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Chapter G

A Digital Resource Model of the Middle Pennsylvanian Pond Creek Coal Zone, Pottsville Group, Central Appalachian Basin Coal Region

By Leslie F. Ruppert, Susan J. Tewalt, Linda J. Bragg, Gerald A. Weisenfluh, Ernest E. Thacker, Bascombe M. Blake, Jr., Roy S. Sites, Philip A. Freeman, David T. Butler, and Leroy C. Bryant

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2000 RESOURCE ASSESSMENT OF SELECTED COAL BEDS AND ZONES IN THE NORTHERN AND CENTRAL APPALACHIAN BASIN COAL REGIONS

By Northern and Central Appalachian Basin Coal Regions Assessment Team

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ABSTRACT

Coal beds in the Middle Pennsylvanian Pond Creek coal zone of the Pottsville Group are an important resource in the central Appalachian Basin coal region and have been mined for over 100 years. This zone contains a number of distinct coal benches and beds that merge and split. Overall, the coal is low in ash and sulfur and high in calorific value. The digital resource model for the coal zone is based on comprehensive stratigraphic and geochemical databases and geographic information system (GIS) coverages of the coal zone. The model indicates that about 8.7 billion short tons of Pond Creek coal remain out of an estimated original resource of about 11 billion short tons. This resource model for the Pond Creek coal zone must be considered provisional because the correlation of coal beds within the zone, and hence the data used for the assessment, continues to be evaluated in West Virginia.

INTRODUCTION

The Middle Pennsylvanian Pond Creek coal zone (fig. 1) is located in the central Appalachian Basin coal region (fig. 2). In Kentucky (fig. 3), the Pond Creek coal zone is located stratigraphically between the Betsie Shale and Crummies Members of the Pikeville Formation (usage of the Kentucky Geological Survey; Eble and others, 1999) where it is most commonly referred to as the Lower Elkhorn coal bed. In Virginia, the Pond Creek is assigned to the Wise Formation and is most commonly referred to as the Imboden coal. In West Virginia, the Pond Creek is referred to as the Eagle coal of the Kanawha Formation (fig. 3). This report refers to the coal as the Pond Creek coal zone to simplify the stratigraphic nomenclature. Selected references for the Pond Creek coal zone, associated strata, and general geology can be found in Appendix 1.

Coal beds of the Pond Creek coal zone have been mined extensively underground and on the surface, but stratigraphic reporting methods make it difficult to determine how Pond Creek coal production ranks against other top-producing U.S. coal beds. The Eagle and Lower Elkhorn coal zones are reported as separate coals by the Energy Information Administration (EIA) and regional miscorrelations in West Virginia result in some Pond Creek production being attributed to the No. 2 Gas or the Campbell Creek coal beds. Production data for 1998 from the EIA ranked the Lower Elkhorn as the twelfth largest producing coal bed in the Nation and the Eagle as the fifteenth largest producer (Energy Information Administration, 2000).

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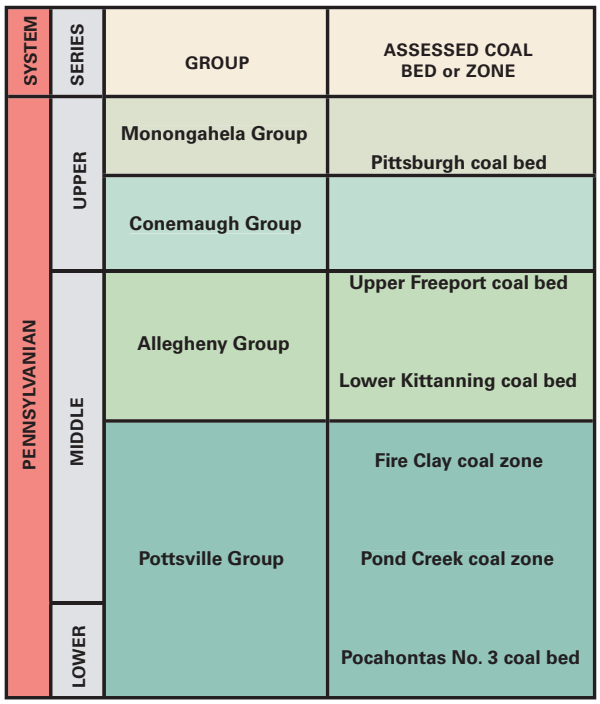

Figure 1. Generalized stratigraphic chart showing relative positions of the six top-producing coal beds or zones assessed in this study. The Lower Kittanning coal bed was assessed for areal extent and geochemistry only. All six coal beds are Pennsylvanian in age.

Although less extensive and generally thinner than other top-producing Appalachian coal beds and zones, Pond Creek coal beds are highly desirable because of their low sulfur and ash contents and high ash-fusion temperatures. Today, coal from mines in the Pond Creek coal zone is used mainly for electric power generation; some of the coal lowest in sulfur is blended with high-sulfur coal to meet emission standards. Many Pond Creek coal deposits are of metallurgical quality and have been mined as coking coal in the past.

The complete outcrop extent of the Pond Creek coal zone can only be estimated at this time because detailed field mapping is not yet complete in West Virginia. However, subtraction of a structural model of the Pond Creek coal zone from U.S. Geological Survey (USGS) digital elevation models (DEM's) yielded an estimated outcrop that roughly matches available outcrop maps. The estimated outcrop is extensive, covering over 8,700 mi^2 (fig. 4). The assessed extent of the Pond Creek coal zone includes 32 counties and almost 3,700 mi^2 in eastern Kentucky, southwestern Virginia, and southern West Virginia (fig. 5). The assessed areal extent was estimated from a combination of outcrop, available stratigraphic data, and a computer-generated 1.17-ft (14-in) coal thickness isoline that was based on data from the Pond Creek coal zone stratigraphic database (Appendix 2). The coal zone assessment area extends from Nicholas County, W. Va., westward and southward to Whitley and McCreary Counties, Ky. (fig. 4). Resources in central West Virginia and northern Tennessee were not assessed because of limited data.

The coal resource assessment model of the Pond Creek coal zone is a cooperative effort between the USGS and the Kentucky Geological Survey (KGS), the Virginia Division of Mineral Resources (VDMR), and the West Virginia Geological and Economic Survey (WVGES).

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GEOLOGY

GEOLOGY OF THE POTTSVILLE GROUP

Rocks of the Pottsville Group in the central Appalachian Basin coal region are lithostratigraphically complex (Eble and others, 1995) because they record a wide range of depositional settings (from shallow marine to terrestrial environments) and tectonic influences (from local to regional) that have been affected by eustatic processes (see Chapters B, F, and H, this report). The Pond Creek coal zone occurs in the middle part of the Pottsville Group and is Middle Pennsylvanian in age (fig. 3). Associated rocks include sandstone, siltstone, shale, claystone, coal, and limestone. The coal zone is underlain by a thick, upward-coarsening, mudstone-dominated sequence that includes a distinctive marine unit termed the Betsie Shale Member (Rice and others, 1987). A less persistent marine unit, the Crummies Member of Kentucky and West Virginia (Rice, Henry, and Chesnut, 1994) and West Virginia (Bascombe

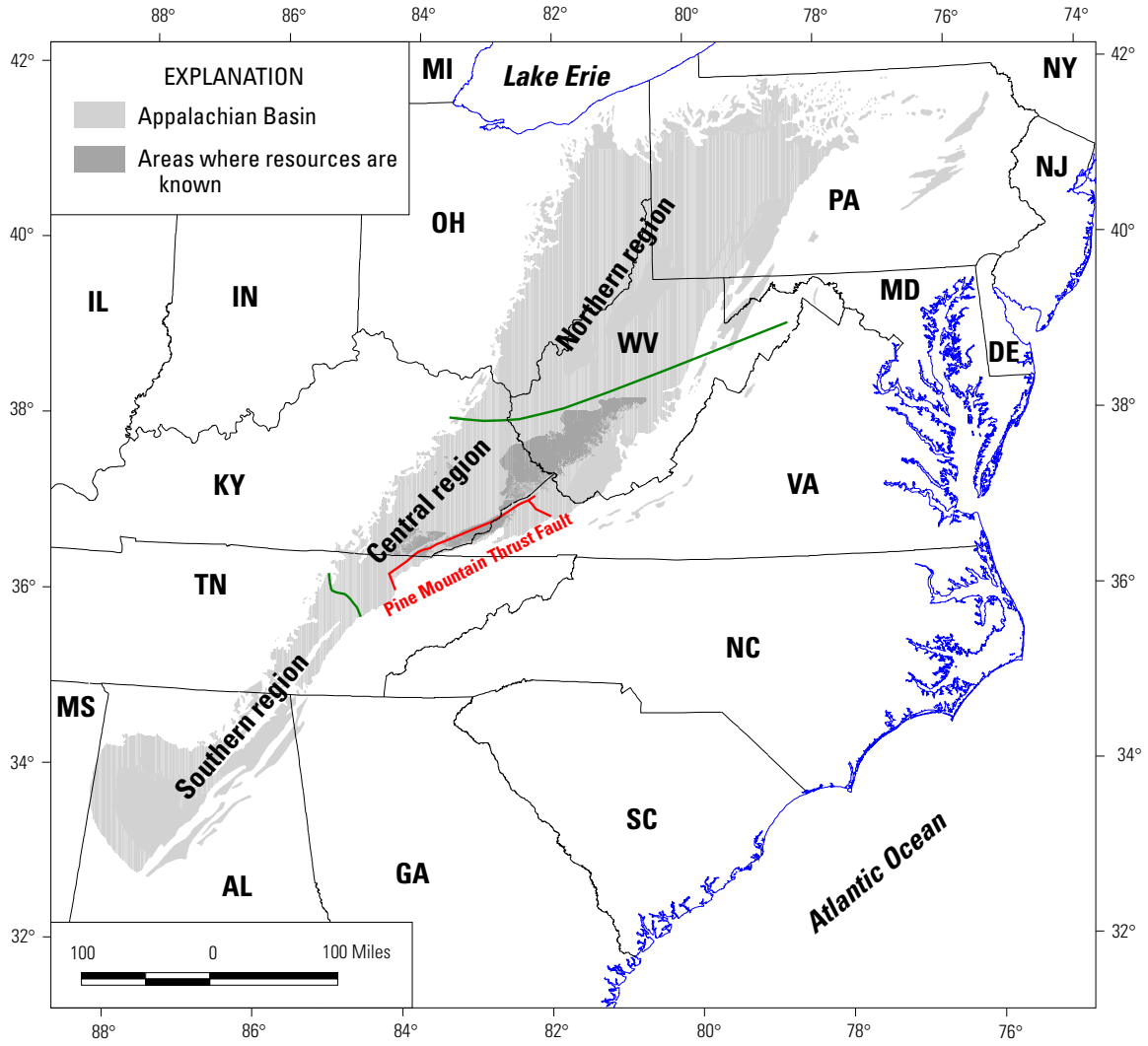

Figure 2. Map showing location of the northern, central, and southern coal regions of the Appalachian Basin. The Pond Creek coal zone is in the central Appalachian Basin coal region in eastern Kentucky, southwestern Virginia, and southern West Virginia.

M. Blake, Jr., KGS, written commun., 1998), is commonly found above the coal zone (fig. 3). In Kentucky, these strata are assigned to the lowermost part of the Pikeville Formation. In West Virginia and Virginia, the same stratigraphic units are in the lower parts of the Kanawha and Wise Formations, respectively. The occurrence of marine to brackish-water deposits both above and below the Pond Creek coal zone indicates that the general depositional setting was that of a low-lying coastal plain episodically inundated by a rising sea level. The principal depositional environments included peat mires, distributary channels and associated floodplain features, river-mouth bars, coastal plains, estuaries, and marine marshes and marine plains.

The Pond Creek coal zone is located within the Appalachian Plateaus physiographic province in the central Appalachian Basin coal region (see Chapter B, this report). In Kentucky, the Pond Creek coal zone is located in the Eastern Kentucky coal field (fig. 6). Structurally, this coal field is a broad, northeast-trending, synclinal structure which results in Pond Creek coal zone surface exposures along the western border of the coal field and in the southeastern corner of the State (fig. 5). This synclinal structure has steep margins in comparison to its gently dipping axial region. Along the axis of the syncline, the coal is approximately 300 to 500 ft below drainage and more than 1,000 ft below the highest elevations. The coal field is divided into two distinct parts by the Pine Mountain thrust fault (fig. 2). Structurally, the southern part is dominated by a steep-sided, flat-bottom syncline, and the northern part by normal faults and anticlinal structures. The normal faults have been documented as syndepositional in origin and their presence influenced sediment distribution and coal thickness (Horne,

SYSTEM	SERIES	PRINCIPAL ROCK-STRATIGRAPHIC UNITS					
		GROUP	KENTUCKY (Modified from Cortland F. Eble, Kentucky Geological Survey, written commun., 1999)	GROUP	VIRGINIA (Modified from James Lovett, Virginia Division of Mineral Resources, written commun., 1998)	GROUP	WEST VIRGINIA (Modified from Bascombe M. Blake, Jr., West Virginia Geological and Economic Survey, written commun., 1998)
PENNSYLVANIAN	MIDDLE	POTTSVILLE	*Peach Orchard coal zone* *Arnett Member* *Hazard/Haddix coal zones* *Magoffin Member* *Fire Clay Rider coal zone* *Fire Clay coal zone (Hazard No. 4 coal bed)* *Whitesburg coal bed* *Kendrick Shale Member* *Amburgy coal bed* *Elkins Fork shale of Morse (1931)* *Upper Elkhorn No. 3 coal zone* *Alma coal zone (Upper Elkhorn Nos. 1 and 2 coal zone)* *Crummies Member* *Pond Creek coal zone (Lower Elkhorn coal bed)* *Little Eagle coal bed* *Betsie Shale Member*	POTTSVILLE	*High Splint coal bed* *Magoffin Member* *Gin Creek coal bed* *Fire Clay coal zone (Phillips coal bed)* *Kendrick Shale Member* *Taggart coal bed* *Taggart Marker coal bed* *Wilson, Upper St. Charles coal beds* *Pond Creek coal zone (Imboden coal bed)* *Betsie Shale Member*	POTTSVILLE	*Coalburg coal bed* *Little Coalburg coal bed* *Arnett Member* *Winifrede coal zone* *Chilton "A" coal bed* *Winifrede Shale Member* *unnamed marine zone* *Fire Clay coal zone* *Cedar Grove (Hernshaw) coal beds* *Dingess Shale Member* *Williamson coal bed* *Campbell Creek limestone of White (1885)* *Peerless coal bed* *No. 2 Gas coal zone* *Powellton coal zone* *Crummies Member* *Eagle "A" coal bed* *Pond Creek coal zone (Eagle coal zone)* *Little Eagle coal bed* *Betsie Shale Member*

Figure 3. Generalized stratigraphic column of the Middle Pennsylvanian Pottsville Group showing major coal and marine zones in Kentucky, West Virginia, and Virginia. The term "Pottsville Group" is used for all three States for simplicity in data entry. Use of the term does not consititute a formal or permanent change to the status of the name in each State.

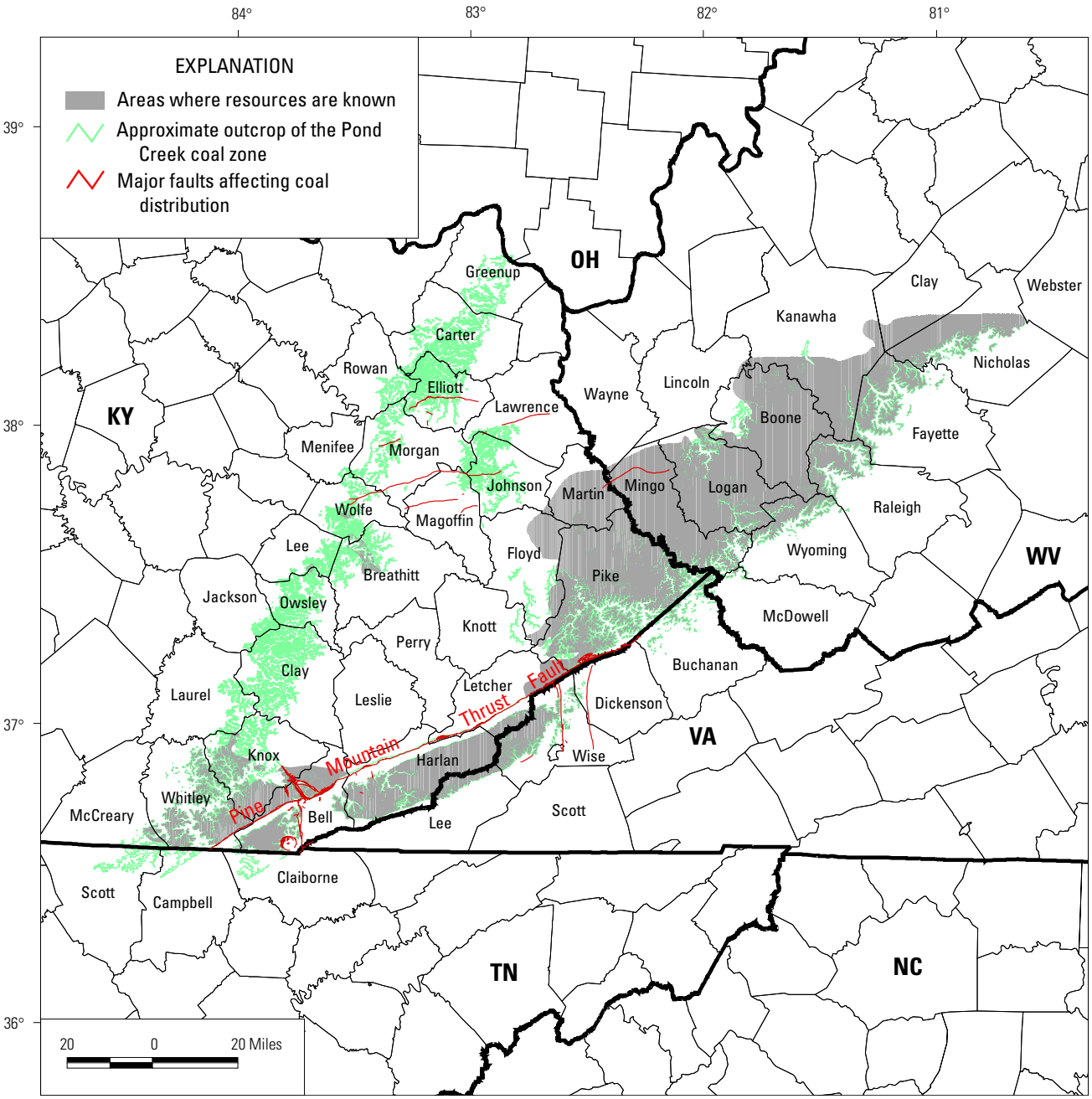

Figure 4. Map showing the estimated generalized outcrop extent of the Pond Creek coal zone horizon (light gray). The Pond Creek coal zone horizon extends over 8,700 mi^2 throughout eastern Kentucky, southwestern Virginia, and southern West Virginia.

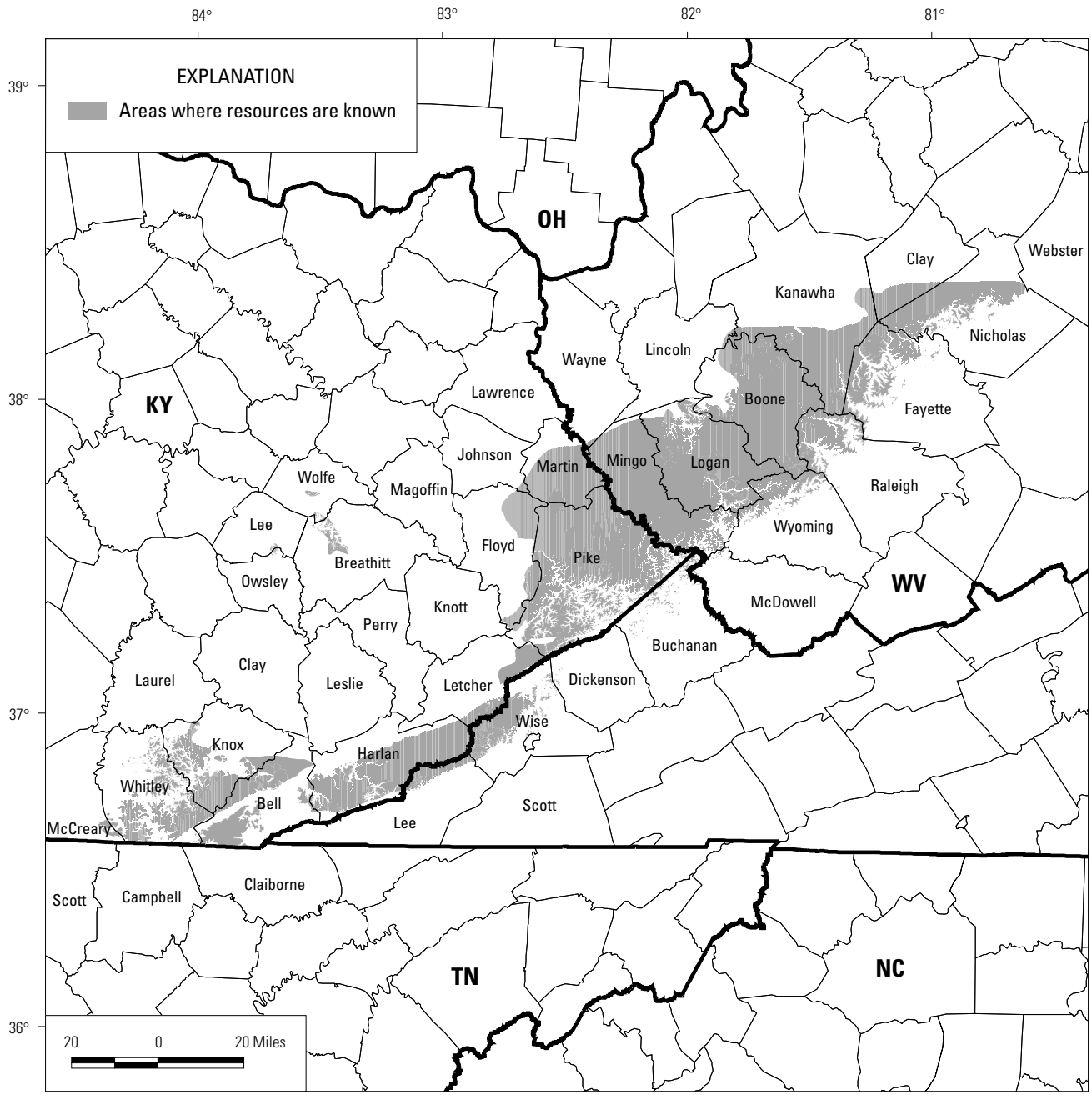

Figure 5. Map showing areas of the Pond Creek coal zone where resources are known. The assessed extent covers about 3,700 mi^2 and 32 counties. The boundaries of the assessment area were derived from a combination of (1) outcrop, (2) extent of available data, and (3) a computer-generated 1.17-ft (14-in) coal-thickness isoline derived from the Pond Creek coal zone stratigraphic database (Appendix 2).

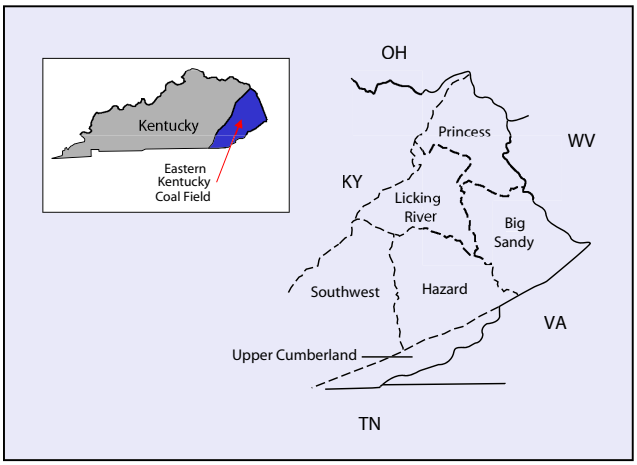

Figure 6. Sketch map showing coal-bearing districts of the eastern Kentucky coal field (Huddle and others, 1963). The Pond Creek coal zone occurs in the Princess, Big Sandy, Licking River, Hazard, Southwestern districts, and in the Middlesboro and Harlan subdistricts of the Upper Cumberland district.

1979). Contemporaneous faults have not been identified in the southern part of the coal field, but distinct anticlinal and monoclinal structures are present, suggestive of penecontemporaneous tectonic control. Some of the structures correlate with variations in Pond Creek coal quality and are believed to have been active tectonically during peat accumulation (Hower, Pollock, and Griswold, 1991). In Virginia, the Pond Creek coal zone is located within the coal fields of southwestern Virginia (fig. 7). The coal field is principally confined to the Cumberland overthrust block on the Pine Mountain thrust fault (Henika, 1994) and is bordered on the east by numerous thrust faults that define a southwest- to northeast-trending boundary accompanied by deformed coal measures. Major geologic structures occur northwestward across the coal field that further deform the coal measures. All structures are transected by several major tear faults across the overthrust block. In West Virginia, the Pond Creek coal zone dips generally northwestward at 100 to 150 ft/mi. This general structural trend is interrupted by the Warfield anticline which extends from the West Virginia border in northern Mingo County eastnortheastward into Kanawha County (fig. 4).

GEOLOGY OF THE POND CREEK COAL ZONE

A plethora of names (Rice, Hiett, and Koozmin, 1994) have been applied to coal beds of the Pond Creek coal zone because of irregular coal distribution and the pattern of historical development of mining districts or regions within the central Appalachian Basin coal region. In Kentucky, coal beds of the Pond Creek coal zone have been named the Bruin or Wolf Creek in the Princess district; the Lower Elkhorn, Bruin, Vires, or Howard in the Hazard district; the Blue Gem or Straight Creek in the Southwestern district; the Lower Elkhorn, Pond Creek, Eagle, or Freeburn in the Big Sandy district; and the Rich Mountain coal zone in the Middlesboro subdistrict and the Imboden or Path Fork in the Harlan subdistrict of the Upper Cumberland River district (see Huddle and others, 1963; fig. 6). In Tennessee, the Pond Creek coal zone includes the Rich Mountain coal zone in the Pine Mountain thrust fault block (fig. 2), and individual bodies of coal are often referred to as the Blue Gem coal bed. The Pond Creek coal zone is in the Southwestern Virginia coal field (fig. 7); equivalents include the Imboden, Upper Bolling, Lower Elkhorn, and Campbell Creek coal. In Logan, McDowell, Mingo, and Wyoming Counties, W. Va., the names Campbell Creek, No. 2 Gas, or Peerless have been applied incorrectly to Pond Creek equivalents (see Blake and others, 1994). In Kanawha, Raleigh, Fayette, and Nicholas Counties, W. Va., the Eagle "A", Eagle, and Little Eagle coal beds are included in the Pond Creek coal zone. The name currently used by the WVGES for the Pond Creek coal zone is the Eagle coal zone (fig. 3).

The Pond Creek coal zone ranges from less than 1 ft to about 40 ft thick and contains multiple coal beds or benches. Individual benches are distinctive and frequently have regional extents; however, minable coal bodies within the zone, which consist of different combinations of individual coal benches, generally lack regional continuity. A reduction in the thickness of minable bodies typically occurs as a result of splitting of one or more benches (fig. 8) by rock partings that are too thick to mine economically. At a regional scale, coal-bed splitting results in thickness discontinuities that can be seen on parts of the minable coal thickness map (fig. 9). Splitting of coal benches within the Pond Creek coal zone is attributable in most cases to contemporaneous clastic influx from crevasse splays or larger distributary systems. Mining difficulties related to splitting coal benches within the Pond Creek coal zone have been described for longwall and conventional underground operations in Kentucky (Nelson and others, 1991; Greb and Popp, 1999; Greb and Weisenfluh, 2000).

Thicknesses of minable beds within the Pond Creek coal zone, generally the result of merging of individual benches, locally exceed 7 ft (fig. 9). In most cases, these thicknesses are in areas where multiple coal benches merge. In-mine studies also have identified very local, linear trends of thick coal in which the coal bed drops downward and thickens into narrow (75–140 ft wide), shallow, trough-like depressions that probably represent small drainages or channels that preceded peat accumulation (Nelson and others, 1991; Greb and Popp, 1999; Greb and Weisenfluh, 2000). However, most coal beds of the Pond Creek coal zone are less than 3.5 ft thick within the assessment area (fig. 9).

In Martin and Pike Counties, Ky. (fig. 4), variations in coal quality correspond to a northeastwardly trending anti-

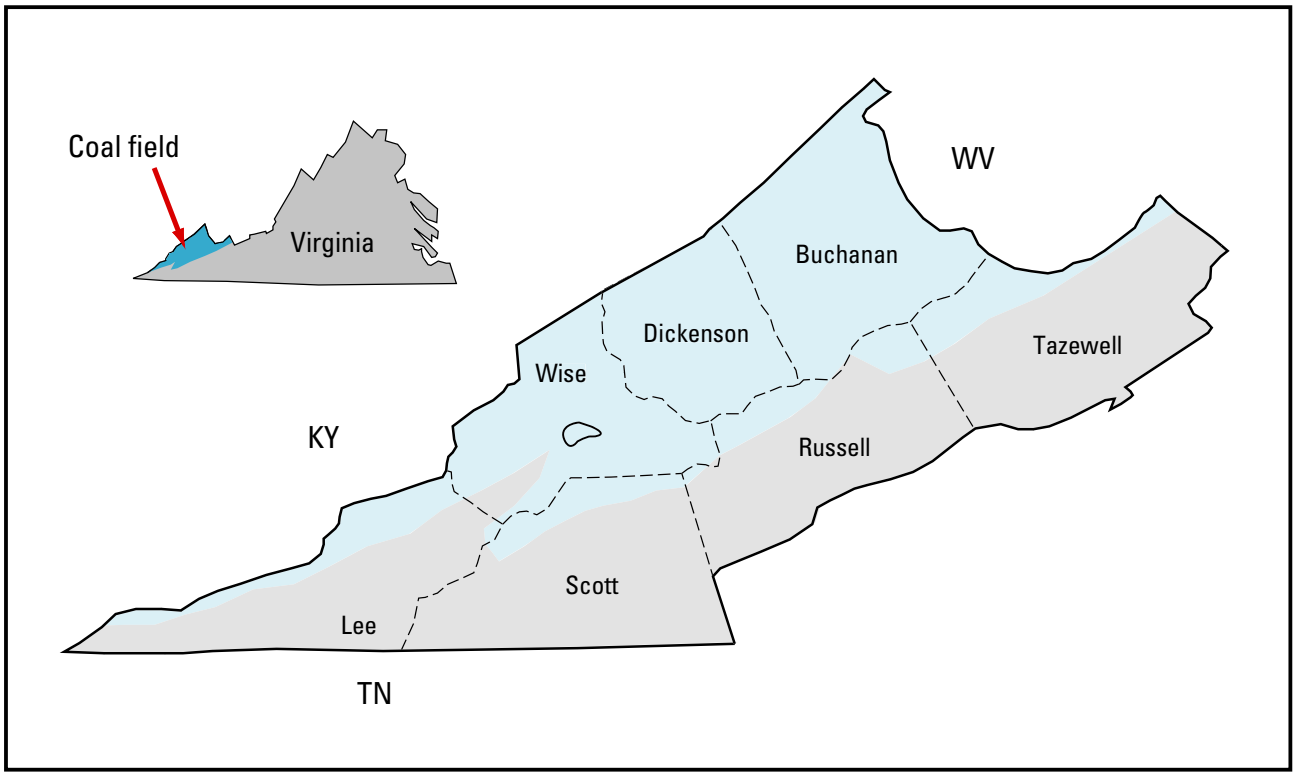

Figure 7. Map showing the location of the southwestern Virginia coal field. The Pond Creek coal zone is present in Lee, Wise, Dickenson, Buchanan, and Norton Counties, Va.

cline (Hower, Pollock, and Griswold, 1991). On the northwest side of the anticline, coal beds within the Pond Creek coal zone have higher sulfur content and differ petrographically from those to the southeast. Throughout the assessment area, local or mine-scale variations in coal quality correlate to sandstone bodies that overlie or split minable Pond Creek coal deposits. Where overlying sandstone bodies replace shale above the coal, sulfur content commonly increases because sandstone allows sulfide-rich waters from marine units overlying the coal zone to infiltrate the coal (Rimmer and others, 1985, 2000). Increased coal bed splitting tends to result in higher ash yields.

MINING HISTORY

The historical development of minable coal within the Pond Creek coal zone has been extensive, and the original resources are significantly depleted. At least 1.3 billion short tons (approximately 45 percent) of the original resources in the Pond Creek coal zone in Kentucky were mined (table 1) or lost to mining as of 1993. Figure 10 shows mined areas for Kentucky, Virginia, and West Virginia.

The development of commercial coal mining in the central Appalachian Basin coal region historically is related to the rise of transportation in the region (Huddle and others, 1963). Prior to the introduction of railroads in the late 1880's, small amounts of coal were mined and transported to markets by wagons over land or by barge along navigable waters. In the early 1900's, there was a dramatic increase in the amount of coal mined and the number and size of underground mines as branch rail lines were built exclusively to transport coal. Following World War II, the construction of improved highways in parts of central Appalachia allowed for the further development of both surface and underground mines in once-remote areas.

Early mining records are scarce and it is difficult to assign known mines confidently to the Pond Creek coal zone. However, Trent (1965) reported that mining in the areas of Pond Creek at Eagle Junction in Fayette County, W. Va., and in northern Pike County, Ky., (fig. 4), started in the early 1880's and 1912, respectively. Coal from the Blue Gem coal bed was mined and shipped as early as the 1880's from northern Tennessee (Glenn, 1925). The Imboden coal bed has been mined since the late 19th century within the Pennington Gap quadrangle, Lee County, Va., and mining was well established by the early 1920's within Lee and Wise Counties (fig. 4) (Giles, 1925).

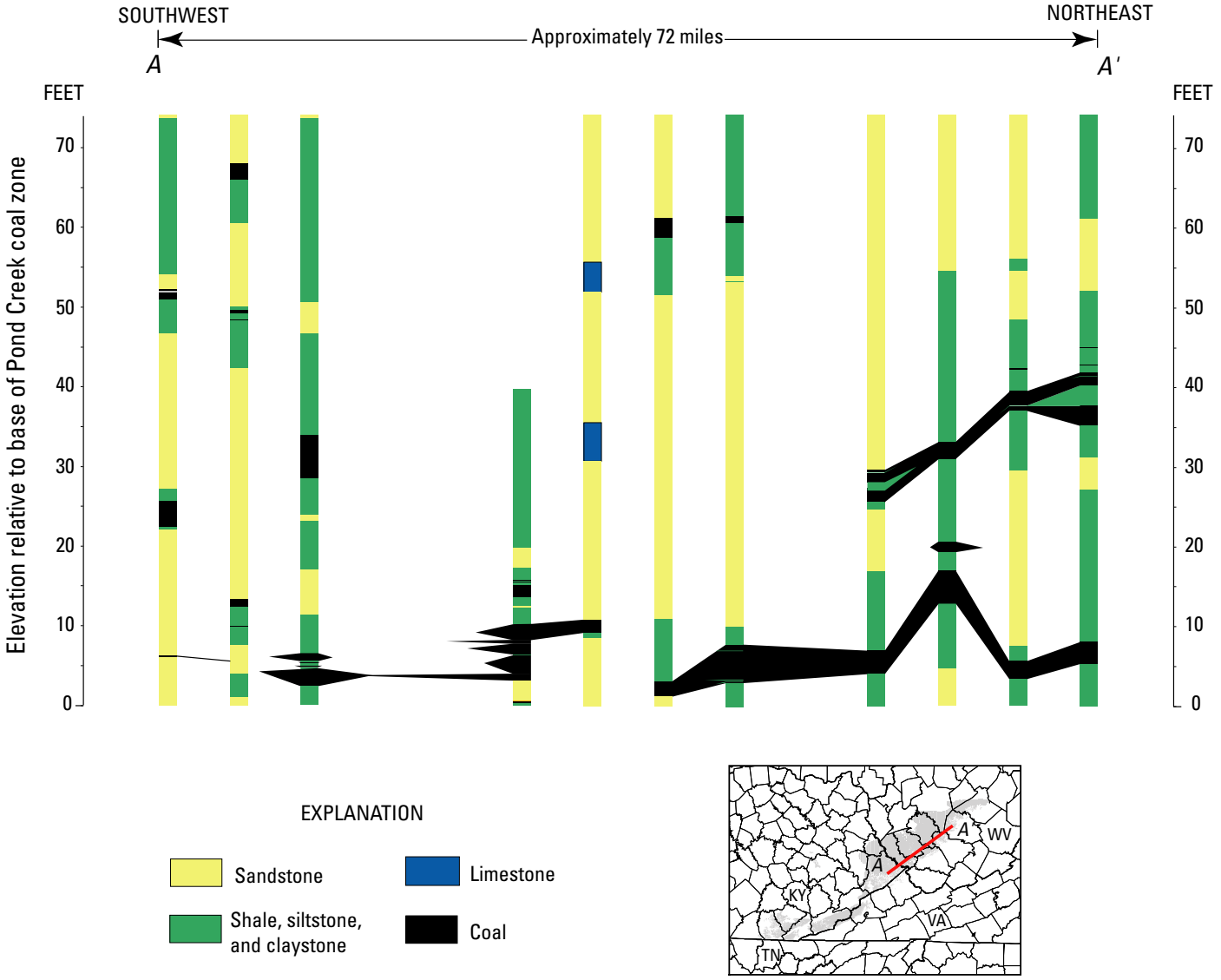

Figure 8. Generalized cross section *A–A′* trending southeast to northwest from Pike County, Ky., to Fayette County, W. Va. Coal beds within the Pond Creek coal zone merge and split to form minable benches of coal. The benches formed in a succession of stratigraphically equivalent mires (Greb and Weisenfluh, 2000). See figure 4 for county names. Vertical exaggeration X5138.

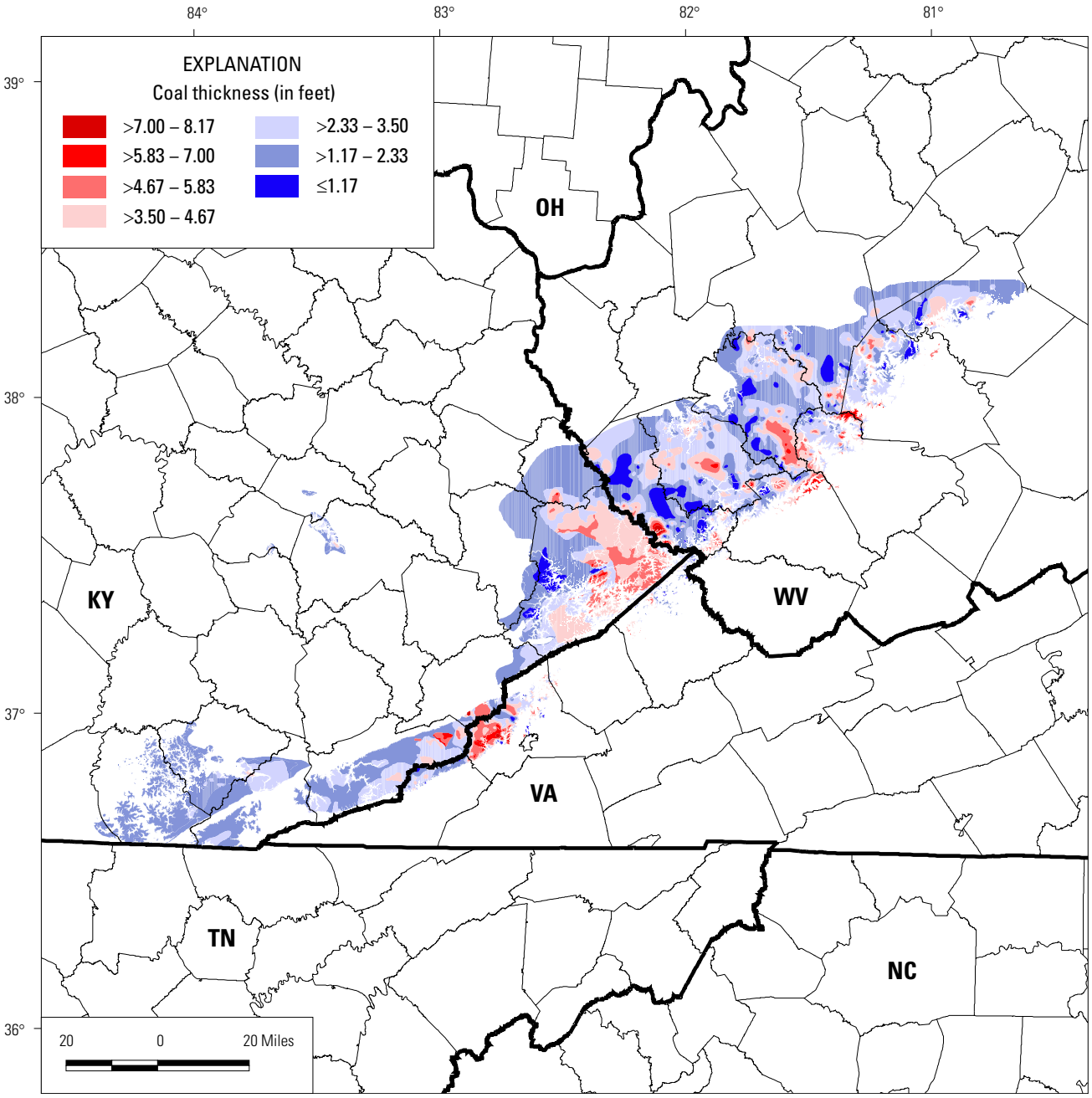

Figure 9. Map showing thickness contours, or isopach lines, for the minable benches of the Pond Creek coal zone. The thickness isopachs, presented in 1.17-ft (14-inch) intervals, were generated from 4,391 stratigraphic records. Because the Pond Creek coal zone is composed of multiple benches that split and merge, the thickness isopach is based only on those benches that may be thick enough to mine rather than on all of the coal within the Pond Creek coal zone.

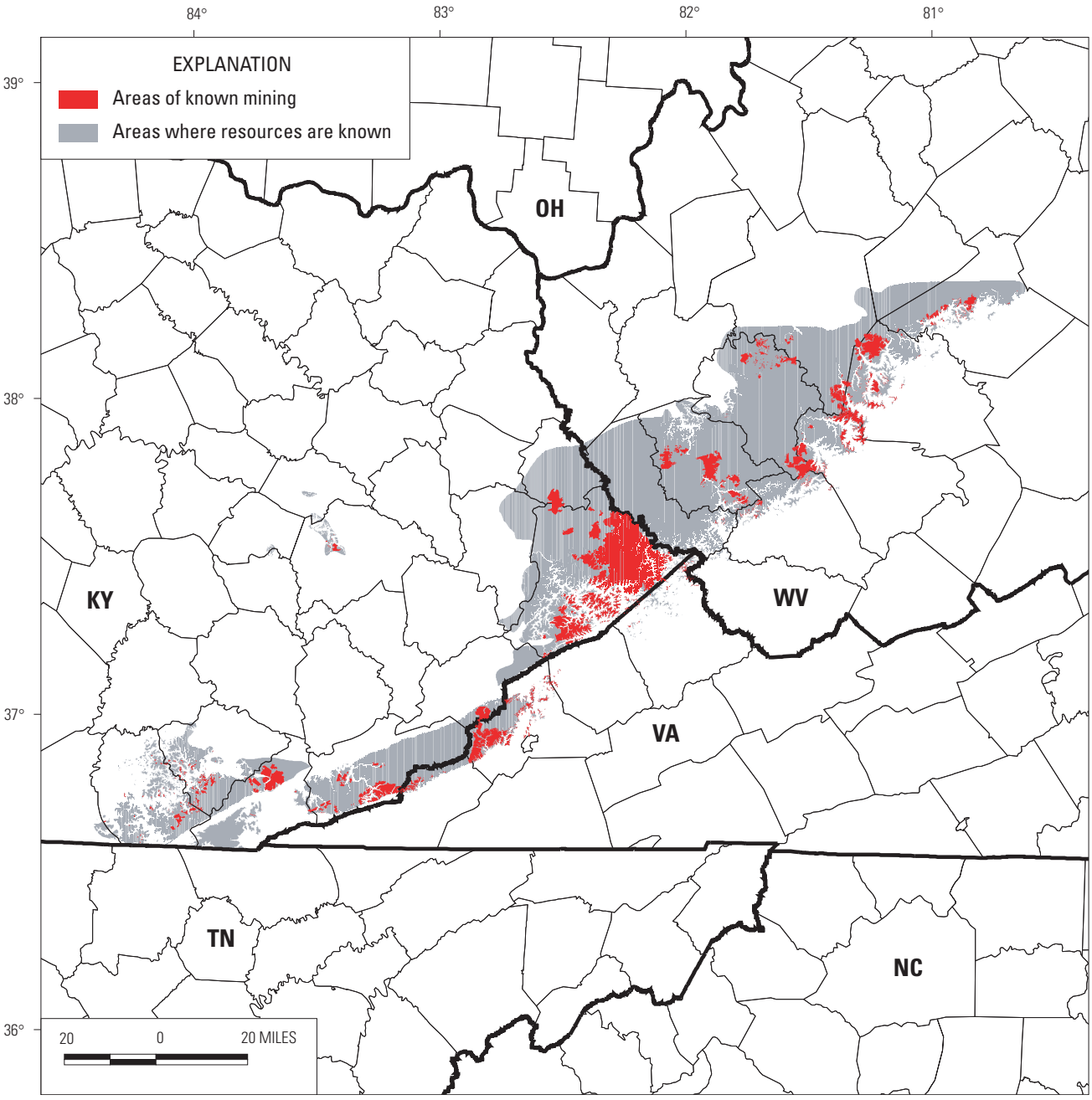

Figure 10. Map showing areal extent of the Pond Creek coal zone (light gray) and mined areas (red). Mined areas include those areas that could be reopened given favorable economic circumstances. Currentness of mined areas is dependent on the date of the source of mining information.

Table 1. Original and remaining resources by State and county for the Pond Creek coal zone, rounded to millions of short tons and two significant figures.

State/County	Original	Remaining	State/County	Original	Remaining
KENTUCKY			Norton	0.014	0.014
Bell	370	300	Wise	430	250
Breathitt	36	31			
Floyd	190	190	**Virginia Total**	570	370
Harlan	810	730			
Johnson	7.8	7.8			
Knox	280	260	**WEST VIRGINIA**		
Laurel	0.75	0.75	Boone	1,200	1100
Lee	2.5	2.5	Clay	140	140
Letcher	210	170	Fayette	400	260
Martin	390	350	Kanawha	680	620
McCreary	15	15	Lincoln	11	11
Owsley	1.8	1.8	Logan	1,200	1100
Pike	2,000	940	McDowell	9.5	9.5
Whitley	280	260	Mingo	910	910
Wolfe	7.3	7.3	Nicholas	450	410
			Raleigh	350	240
Kentucky Total	4,600	3,300	Wayne	15	15
			Wyoming	230	220
VIRGINIA			**West Virginia Total**	5,600	5,000
Buchanan	41	36			
Dickenson	3.9	0.91			
Lee	97	84	**Grand Total**	**11,000**	**8,700**

Most of the coal in the Pond Creek coal zone has been mined underground by room-and-pillar methods. Currently in Kentucky, the largest conventional mines (annually producing more than one million short tons) are located in northern Pike County and southern Martin County and are operated by Sidney Coal Company, Inc., and Alliance Coal. The Upper Big Branch mine, located in West Virginia, is the largest underground mine operating in the Pond Creek coal zone. This mine is the eighth largest underground mine operating in the Appalachians, and produced approximately 5.2 million short tons of coal in 1998 (Fiscor, 2000). In Virginia, the largest underground mine in the Pond Creek coal zone is the North Fork Coal Corporation No. 3 mine. Only two longwall mines produce Pond Creek coal (Harris No. 1 mine and the Eagle Nest mine) and both are located in Boone County, W. Va. (Keystone Coal Industry Manual, 1998). Although surface mining accounts for less than 10 percent of annual Pond Creek coal production, two large surface mines continue to operate in Wise County, Va.—the Matt Mining Company, Inc., No. 3 Strip; and A&G Coal Corporation Strip No. 8.

In the Southwestern District of Kentucky (fig. 6) the Pond Creek is known as the Blue Gem coal bed. In contrast to most underground mines, which require relatively thick (>3.5 ft) bench heights and large available tonnage to ensure profitability, mines in the Blue Gem coal can be small (annually producing less than 50,000 short tons) and operate in very thin benches (1.17–2.33 ft). Thin Blue Gem coal can be mined underground profitably because the coal has a low ash-fusion temperature and commands a very high price from utilities operating wet-bottom scrubbers (Hower, Hiett, and others, 1994).

Pond Creek coal production was important in the latter part of the 20th century (fig. 11; Appendix 3) because it is high-quality steam coal. Coal production data are available for all three states in which the Pond Creek coal zone exists (Kentucky, Virginia, and West Virginia) for the years 1985 through 1996 (Appendix 3). During this time period, over 276 million short tons of Pond Creek coal were mined, annually averaging over 23 million short tons. Approximately 539 million short tons of Pond Creek coal were produced in Kentucky over the last 90 years (John K. Heitt, Kentucky Department of Mines and Minerals, written commun., 2000). Bell, Knox, Letcher, Martin, Pike, and Whitley Counties, Ky. (fig. 5) each have produced over 15 million short tons of coal (fig. 12; Appendix 4). The Pond Creek coal zone has been mined in Buchanan, Dickenson, Lee, and Wise Counties, Va.; Wise County was the top producer throughout the mid-1980's and 1990's (fig. 13; Appendix 5). Of the approximately 14.2 million short tons of Pond Creek coal production reported in that time frame, about 12.1 million short tons were mined in Wise County. West Virginia produced about 96 million short tons of Pond Creek coal between 1982 and 1996 (Appendix 6) and production generally is increasing (fig. 14).

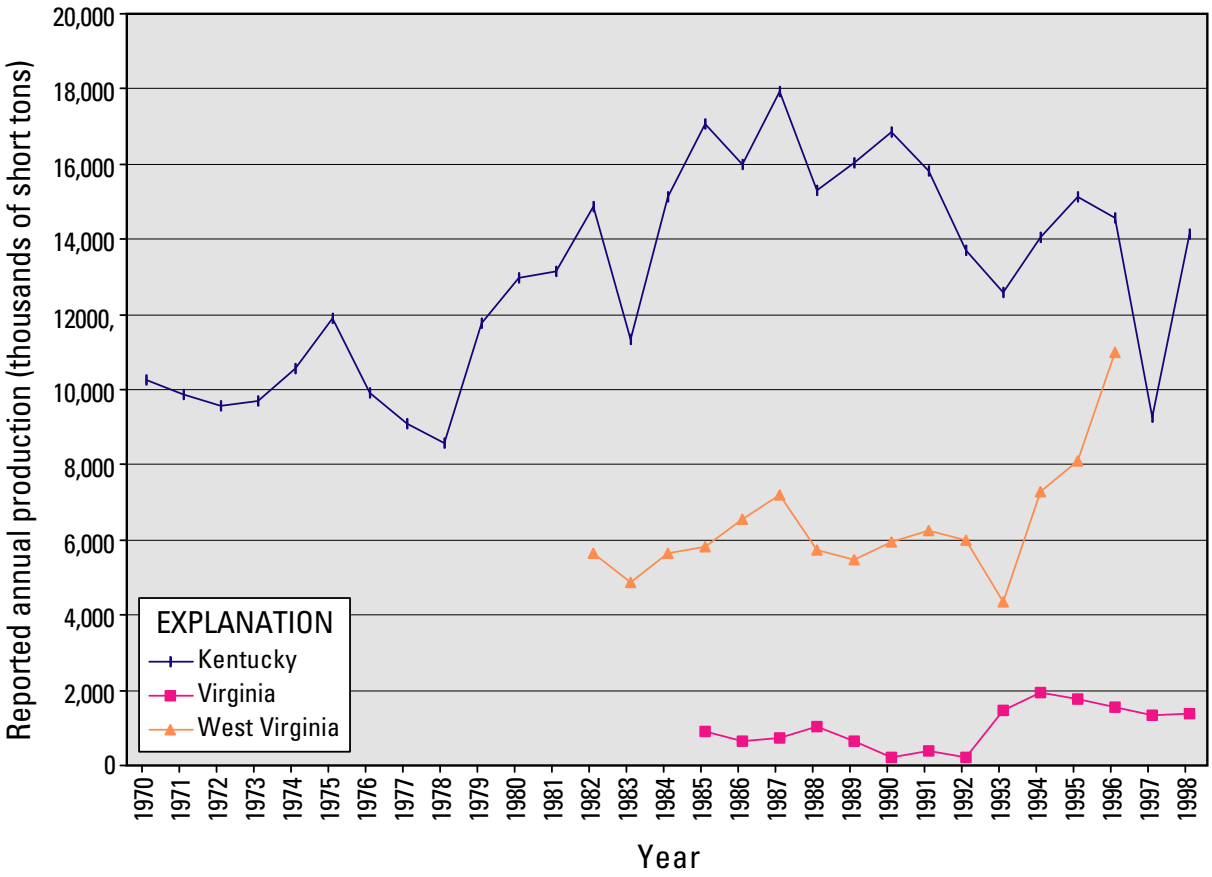

Figure 11. Graph showing reported annual production (in thousands of short tons) from the Pond Creek coal zone in Kentucky, Virginia, and West Virginia from 1970 through 1998. Sources: Sweet (1988, 1989, 1991), Sweet and Nolde (1992, 1993, 1994, 1995, 1996, 1997a,b, 1998, 1999), Gayle H. McColloch (West Virginia Geological and Economic Survey, unpublished search of West Virginia Office of Miner's Health, Safety, and Training—Safety Information System (MHST-SIS) database, 1997), and John K. Hiett (Kentucky Department of Mines and Minerals, written commun., 2000).

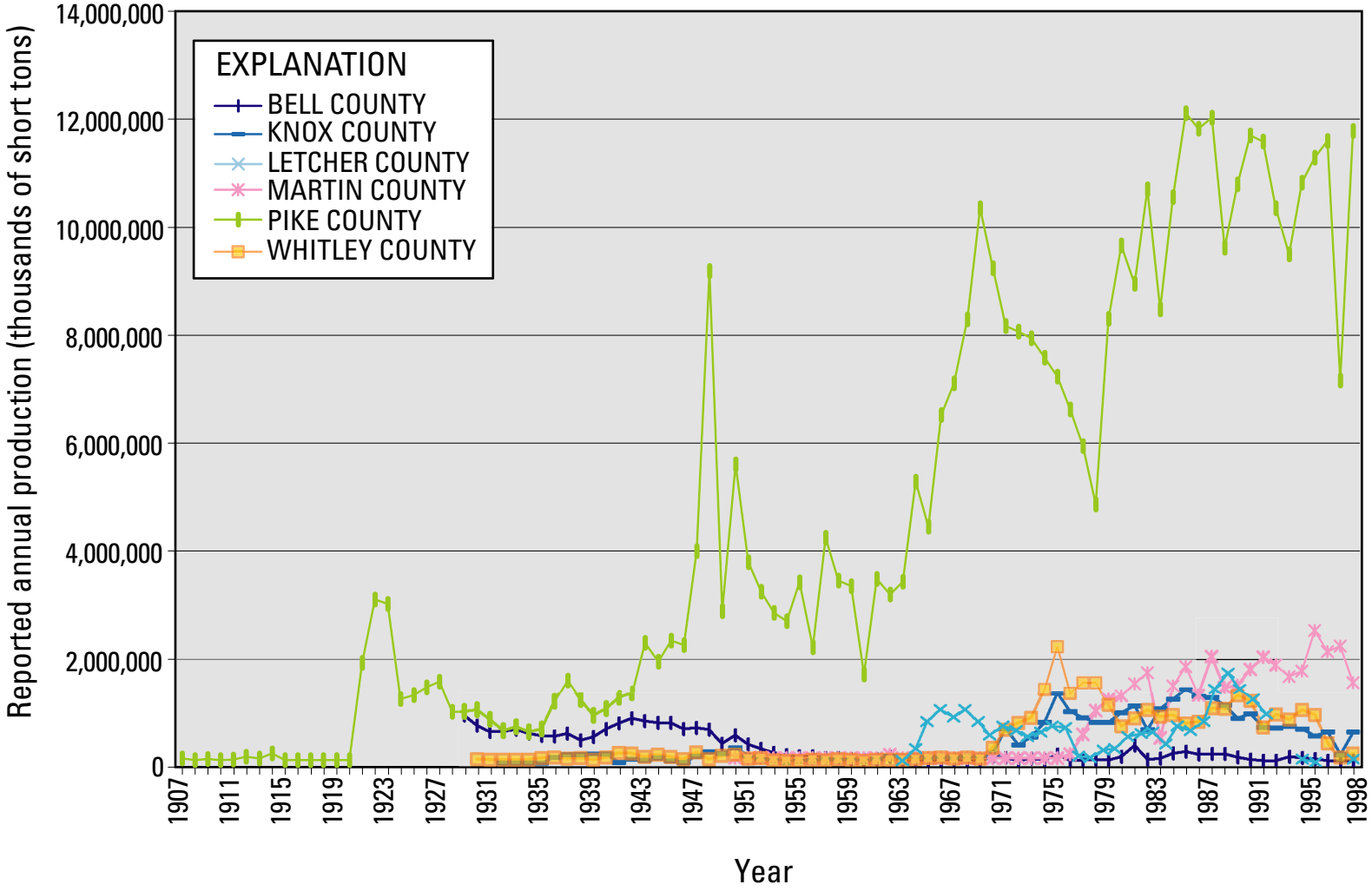

Figure 12. Graph showing reported annual production (in thousands of short tons) of the Pond Creek coal zone in the six top-producing counties in Kentucky from 1907 to 1998. Source: John K. Hiett (Kentucky Department of Mines and Minerals, written commun., 2000).

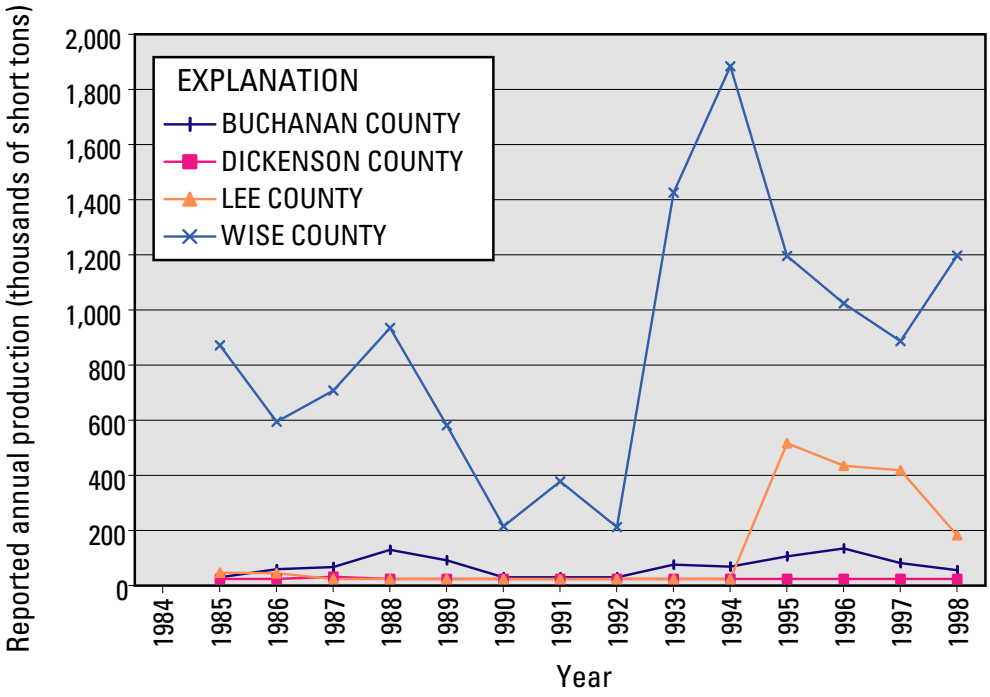

Figure 13. Graph showing recent reported annual production (in thousands of short tons) of the Pond Creek coal zone in Virginia, by county, from 1984 to 1998. Sources: Sweet (1988, 1989, 1991), Sweet and Nolde (1992, 1993, 1994, 1995, 1996, 1997a,b, 1998, 1999).

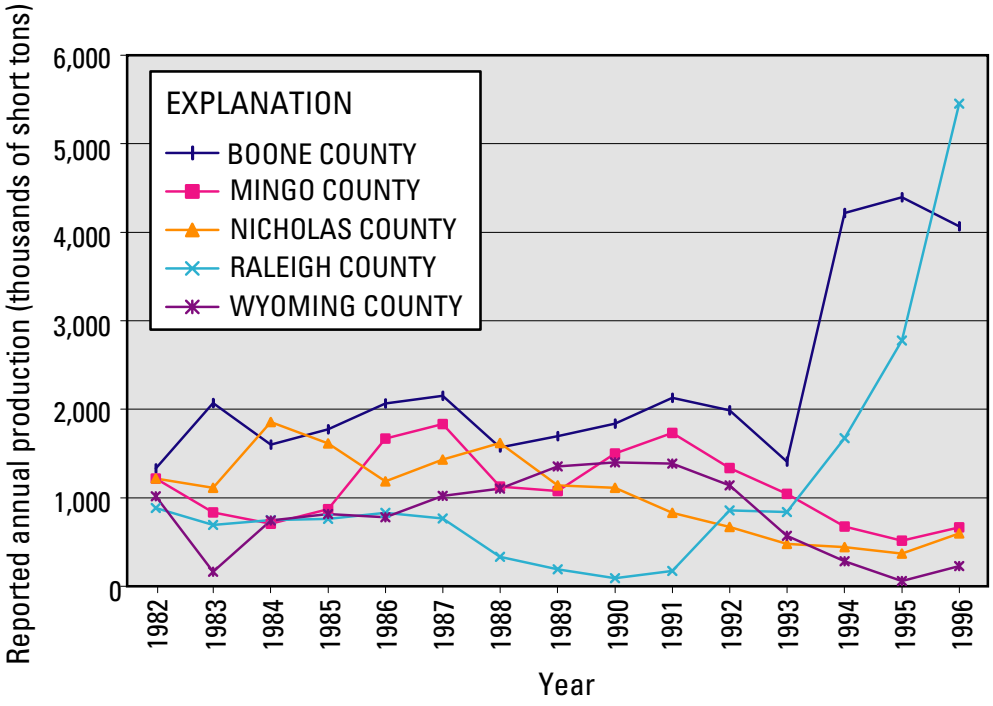

Figure 14. Graph showing recent reported annual production (in thousands of tons) of the Pond Creek coal zone in the five top-producing West Virginia counties from 1982 to 1996. Only counties with annual production of more than 10 million short tons are shown. Source: Gayle H. McColloch (West Virginia Geological and Economic Survey, unpublished search of West Virginia Office of Miner's Health, Safety, and Training—Safety Information System (MHST-SIS) database, 1997).

ASSESSMENT METHODOLOGY

DATABASES

Both a stratigraphic and geochemical database were the primary tools used to assess the Pond Creek coal zone. Public stratigraphic records for this study were obtained from the State geological surveys. The data locations are shown in figure 15. The WVGES provided preliminary stratigraphic data to the USGS for this assessment; because WVGES is currently updating correlations for all State-held stratigraphic records, the resource model of the Pond Creek in West Virginia is likely to change. Data from Virginia were obtained from USGS's National Coal Resources Data System (NCRDS) and coal-zone correlations were checked by viewing the data in cross sections. Kentucky data were derived from two separate KGS databases. The Kentucky Coal Resources Information System (KCRIS) contains total coal thickness, bottom elevation, and, in some cases, total parting thickness measurements from outcrops, roadcuts, and surface and underground mines. The second database contains records of borehole information obtained from coal companies and government agencies. The borehole data also contain measurements of rock strata above and below the Pond Creek coal that are important for assessing mining characteristics. Because some of KGS's stratigraphic records are proprietary, digital maps of the Pond Creek coal zone were created in Kentucky and combined with the Pond Creek assessment model prepared by USGS personnel. The Pond Creek stratigraphic database (Appendix 2) contains approximately 4,013 public records from all three States (fig. 15); only coal benches most likely to be mined were tagged in the database and used to calculate resources.

The Pond Creek coal zone geochemical database (Appendixes 7, 8) was derived from the USGS and KCRIS databases (see Appendix 9 references). The database consists of 297 analyses, on an as-received basis, from Kentucky (245), Virginia (10), and West Virginia (41). All of the analyses are located within the Pond Creek coal zone assessment area and georeferenced by latitude and longitude coordinates (fig. 16). Of the 297 records, one record contained only data for total moisture content; 296 records contain data for ash yields, sulfur and sulfur-dioxide contents, gross calorific values, apparent rank, and total moisture content; and 88 contain analyses for as many as 86 different trace elements. Additional information on data sources, handling, averaging, and formatting are detailed in Appendixes 8 and 9. The geochemical database, metadata, and references can be downloaded in ASCII format.

GEOGRAPHIC INFORMATION SYSTEM (GIS)

The outcrop area of the Pond Creek coal zone in Kentucky was compiled from U.S. Geological Survey 7.5-minute geologic quadrangle maps (Appendix 10). Where the coal had not been completely mapped, its position was inferred, where possible, based on underlying or overlying beds. For Virginia, the VDMR provided digital data for the extent of the outcrop. Complete outcrop data in West Virginia were not available, but outcrop lines provided by the WVGES (on mylar film or paper sheets at 1:24,000 and 1:48,000 scales) were digitized by the USGS and joined with those from Kentucky and Virginia in a geographic information system (GIS). A minor amount of the Pond Creek coal zone exists in northernmost Tennessee, but this outcrop was not incorporated into the assessment.

The limits of the Pond Creek coal zone resource assessment area (fig. 5) were defined using a combination of outcrop lines, data-point distribution, and a 1.17-ft thickness line (isoline) using criteria from Wood and others (1983) and bounding faults. The mined area coverage was created by combining information from the State geological surveys (fig. 10). The accuracy of mined areas varies based on the source of information and dates of completion. Generalized outlines of mined-out areas in Kentucky were collected from the Kentucky Department of Mines and Minerals (KDMM) and transferred to 1:100,000-scale base maps. Individual mine boundaries were not documented. The KDMM maps were completed in 1993 and only a few new Kentucky mines have been added since that time. The KGS updated these files after completion of this assessment. Mined areas in Virginia were provided by the VDMR and are current as of 1994. In West Virginia, mined areas, last updated in the early- to mid-1980's, were digitized from 1:24,000-scale mylar films and 1:48,000-scale transparencies that were made available by the WVGES.

Part of the structure-contour map for the Pond Creek coal zone (fig. 17) was provided in digital format by the KGS. In Kentucky, all elevation data from the KCRIS and borehole databases were plotted on 1:100,000-scale base maps, and were contoured manually where data density was sufficient. In areas of insufficient data, elevation contours were estimated from nearby outcrop elevations or by interpolating the surface of the Pond Creek coal zone from other

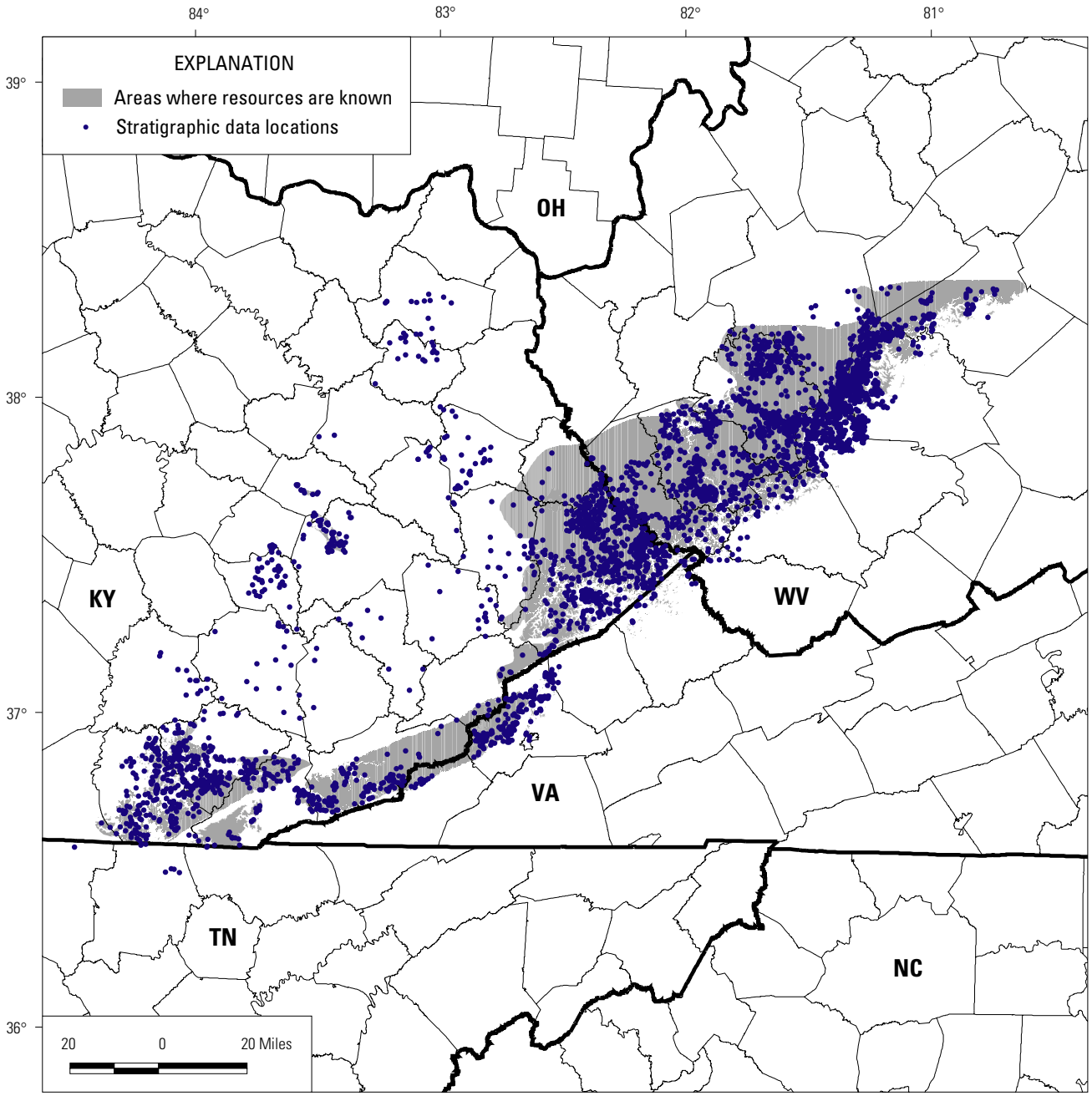

Figure 15. Map showing point locations for stratigraphic records that were used to model the coal resources of the Pond Creek coal zone. Point identifier or record name, latitude, longitude, coal elevation, and coal thickness for all records can be downloaded from Appendix 2 in ASCII format. See figure 4 for county names.

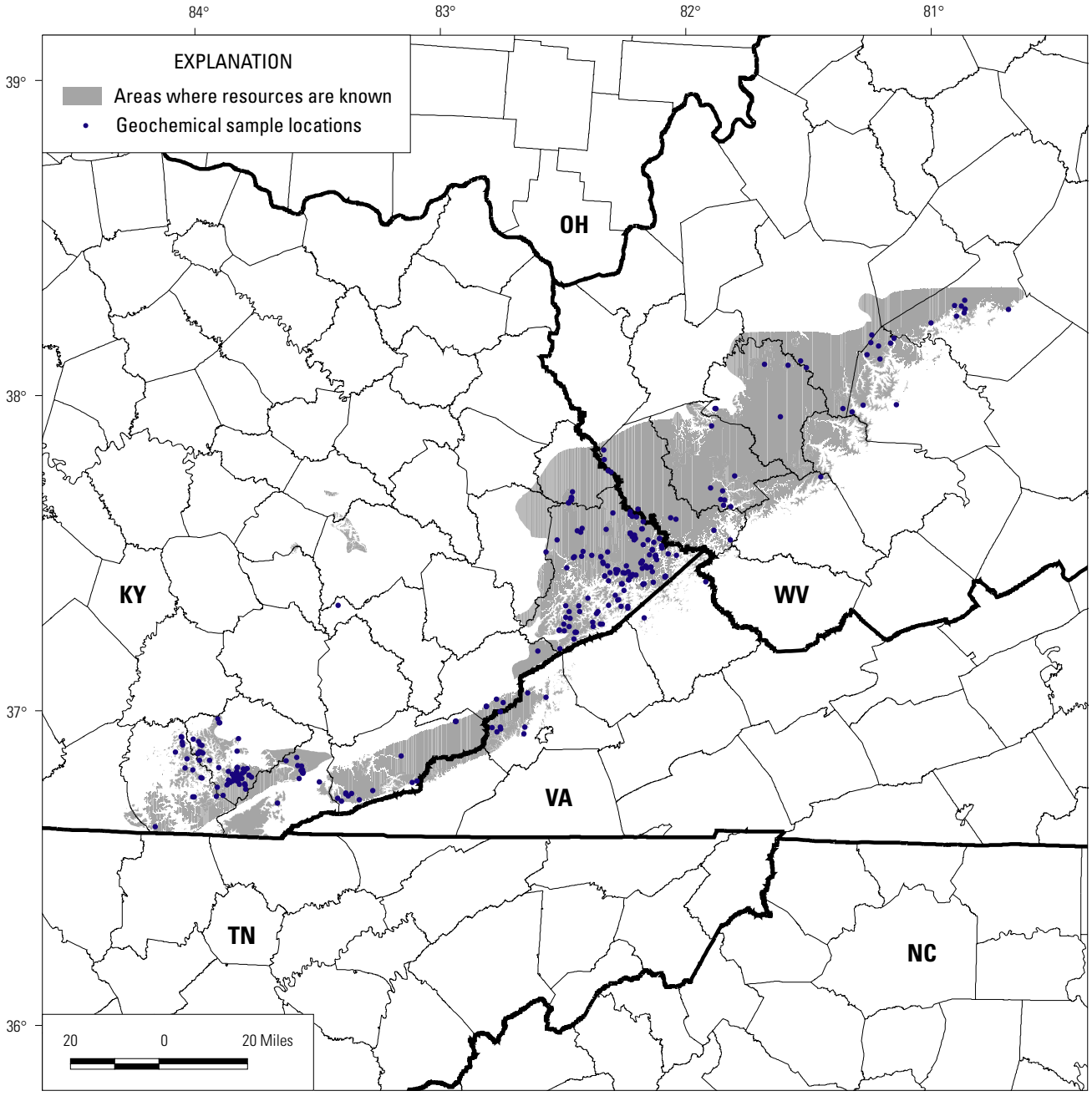

Figure 16. Map showing point locations of geochemical samples of the Pond Creek coal zone for which records are publicly available and located by latitude and longitude. All publicly available geochemical data can be downloaded in ASCII format from Appendix 7. See figure 4 for county names.

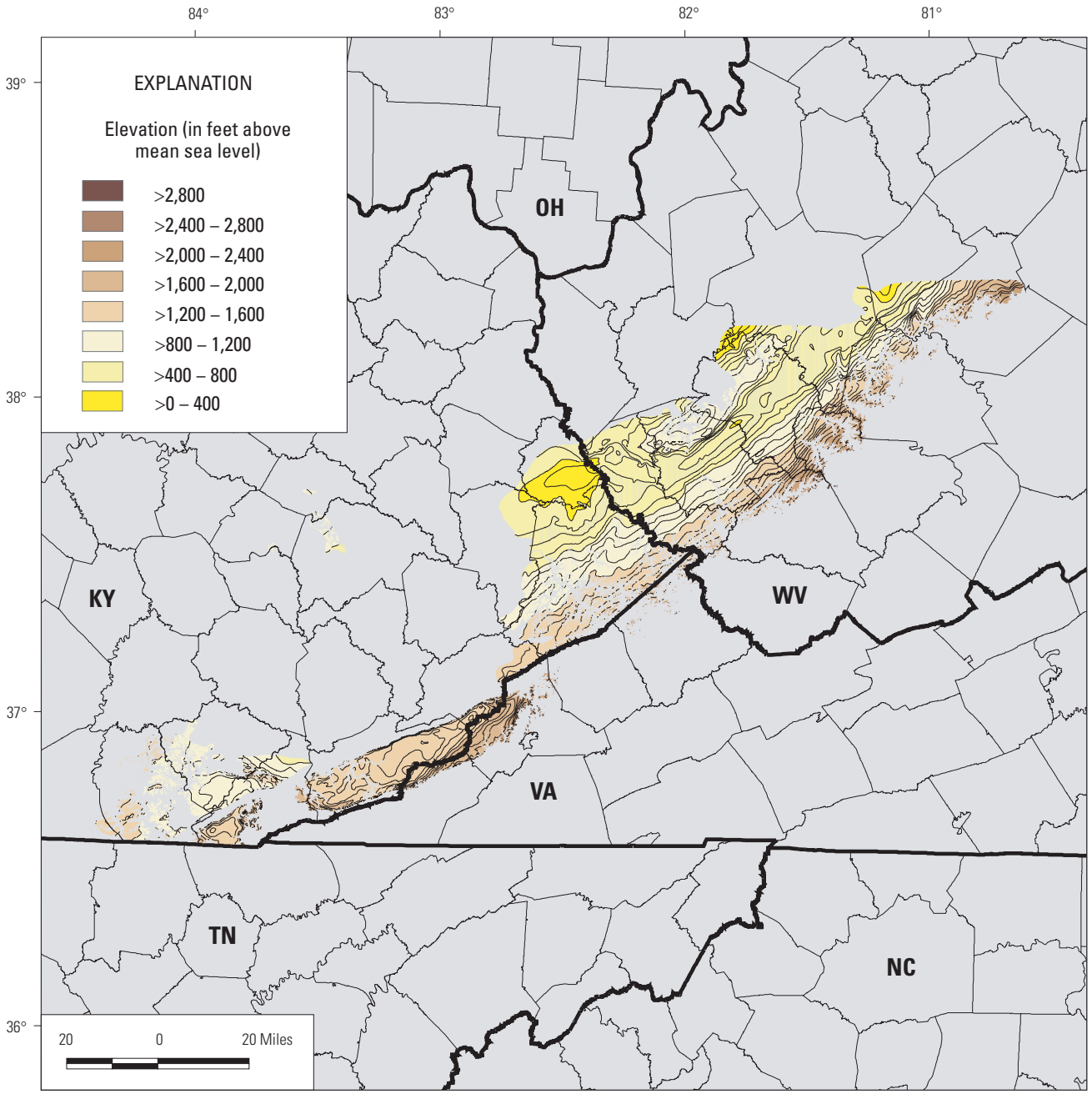

Figure 17. Structure-contour map of the Pond Creek coal zone. The contour elevations are presented in 100-ft intervals; however, for visual acuity, most contours were colored in 400-ft intervals. Approximately 137,400 elevations were used to generate the map. See figure 4 for county names.

structurally mapped coal beds on the basis of average interburden thicknesses derived from borehole data. Contour lines provided by the WVGES and KGS were converted into points and combined with stratigraphic data from Virginia. The resulting points and a file of regional structural faults were entered into geologic modeling software (EarthVision[7]), to create a complete elevation surface of the coal. The maximum elevation of the Pond Creek coal zone is 3,000 ft and is in Raleigh County, W. Va. (fig. 17).

The generalized overburden thickness (fig. 18) was calculated by subtracting the structure-contour grid from the grid derived from USGS 1:100,000-scale digital elevation models. The contour intervals used for overburden thickness are 0–200 ft, >200–500 ft, >500–1,000 ft, >1,000–2,000 ft, and >2,000–3,000 ft and are based on criteria from Wood and others (1983). The thickest overburden is 2,553 ft and is found in Harlan County, Ky. Because the cell sizes used in the surface-elevation grid and structure-contour grid were large (330 ft) and because topography is highly dissected, there were occasional errors in the location of the 0–200 ft category that were eliminated by buffering inward 75 m parallel to the outcrop.

The thickness contours of the minable benches of the Pond Creek coal zone (fig. 9) were generated from 4,391 thickness records. Identified partings and bone coal over 0.38 inches thick were excluded (Wood and others, 1983). Because coal beds within the Pond Creek coal zone merge and split to form coal of variable thickness, the KGS developed guidelines based upon coal and non-coal partings (interburden) thicknesses and industry practice to identify "minable" Pond Creek coal benches. The USGS followed the KGS guidelines in this assessment to identify "minable" thicknesses in the Virginia and West Virginia databases so that similar methods were applied to all Pond Creek coal data. For surface minable coal (within 200 ft of the surface), the thickness of a single coal interval (defined as having non-coal rock types above and below) had to be at least 1.17 ft. Additional benches were included if the total thickness of the intervening non-coal material was less than half as thick as the additional coal bench. Multiple coal intervals were included if the total non-coal intervals were no more than half as thick as the total additional coal intervals. If no single coal interval was at least 1.17 ft thick, the thickest coal within the stratigraphic zone was labeled Pond Creek. Similar guidelines and methodology were applied to the Fire Clay coal zone (Chapter F, this report).

All thickness data points from the Pond Creek coal stratigraphic database were transferred to a grid, contoured, and imported into a GIS. The Kentucky part of the thickness model was later clipped and replaced with a newly released, manually contoured map of the Pond Creek coal zone (Lower Elkhorn coal bed) in Kentucky (Thacker and others, 2000; fig. 19). Because the calculation methods for thickness intervals are based on computer modeling in West Virginia and Virginia and manual contouring in Kentucky, contour lines may not match across the State lines (fig. 9).

RESOURCE METHODOLOGY

Original and remaining resources were calculated for the Pond Creek coal zone using the thickness and overburden coverages described above. This assessment uses the USGS reliability categories of identified and hypothetical resources (calculated for areas less than and farther than 3 mi from a coal-thickness measurement, respectively) based on criteria specified by Wood and others (1983). These two categories were generated in order to characterize the data spacing used to prepare the resource estimates.

To prepare for resource calculations (as specified by Wood and others, 1983), data for outcrop, coal and overburden thickness, mined areas, reliability categories, and counties were merged into a single data set representing resource subcategories. Resource tonnages were calculated by multiplying the area of each polygon by its average coal thickness and by a tonnage factor of 0.445 short tons/ft-m^2 (the weight of bituminous coal per unit volume). Tonnage values were compiled in a spreadsheet for the summation of original and remaining resources for each county aggregated by reliability, coal thickness, and overburden thickness. Table 1 shows original and remaining resource totals by State and county. Original and remaining resources calculated for the USGS coal thickness, overburden, and reliability categories are shown by State in figures 20 to 22 and by State and county in Appendixes 11 and 12.

GEOCHEMISTRY

The Pond Creek coal zone geochemical samples were aggregated to obtain representative analyses of the zone's coal chemistry (Appendix 7). The analyses allow for the comparison of geochemical parameters of representative samples at any one location within the coal zone and serve to eliminate the well-documented coal-quality variation within individual benches (Hower and Bland, 1989; Hower Pollock, and Griswold, 1991; Hower, Rimmer, and Bland, 1991; Hower, Hiett, and others, 1994; Hower, Taublee, and others, 1994; Hower and others, 1997; Greb and Weisenfluh, 2000). In addition, most of the sample localities in the geochemical database are located in areas that have been mined and thus are probably representative of only part of the Pond Creek coal resource. Samples of Pond Creek coal obtained outside of the assessed area (fig. 5) were removed from the geochemical database. Steps for processing and eliminating data analyses can be found in

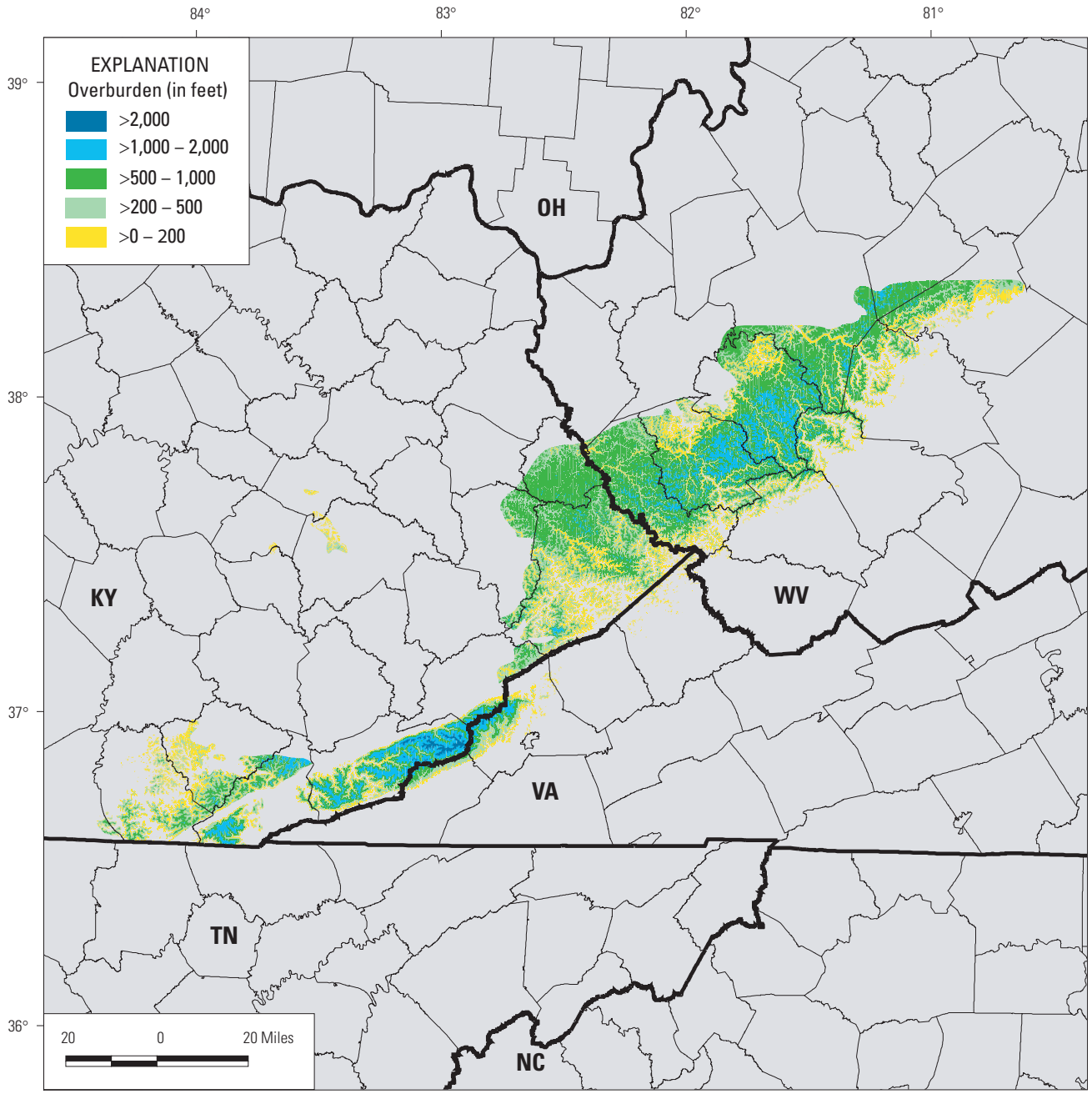

Figure 18. Overburden thickness map of the Pond Creek coal zone. The overburden thickness map was calculated by subtracting the structure-contour grid on the top of the Pond Creek coal zone from DEM (digital elevation model) topography. The contour intervals for overburden thickness are variable, based on criteria from Wood and others (1983). Although the deepest category is classified as 2,000 to 3,000 ft, the greatest overburden thickness is actually 2,553 ft and is in Harlan County, Ky. See figure 4 for county names.

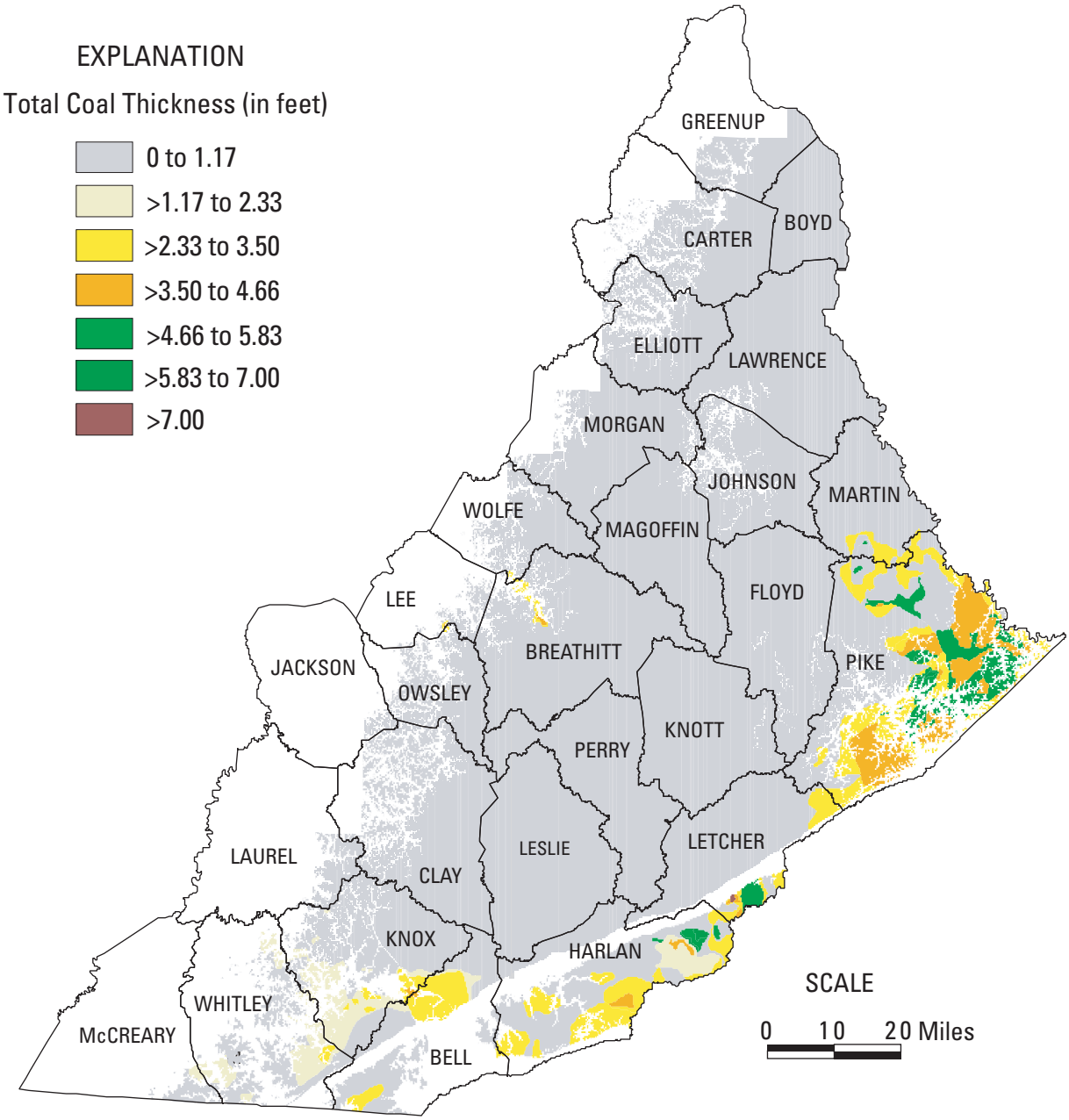

Figure 19. Map showing the total coal thickness data of the Pond Creek coal zone (Lower Elkhorn coal bed) in eastern Kentucky that were used to replace Kentucky thickness data in this report. Thacker and others (2000) plotted public and confidential thickness data on 1:100,000-scale base maps, manually contoured the data so that contour lines would not cross coal split discontinuities, and digitized the resulting map. Modified from Thacker and others (2000).

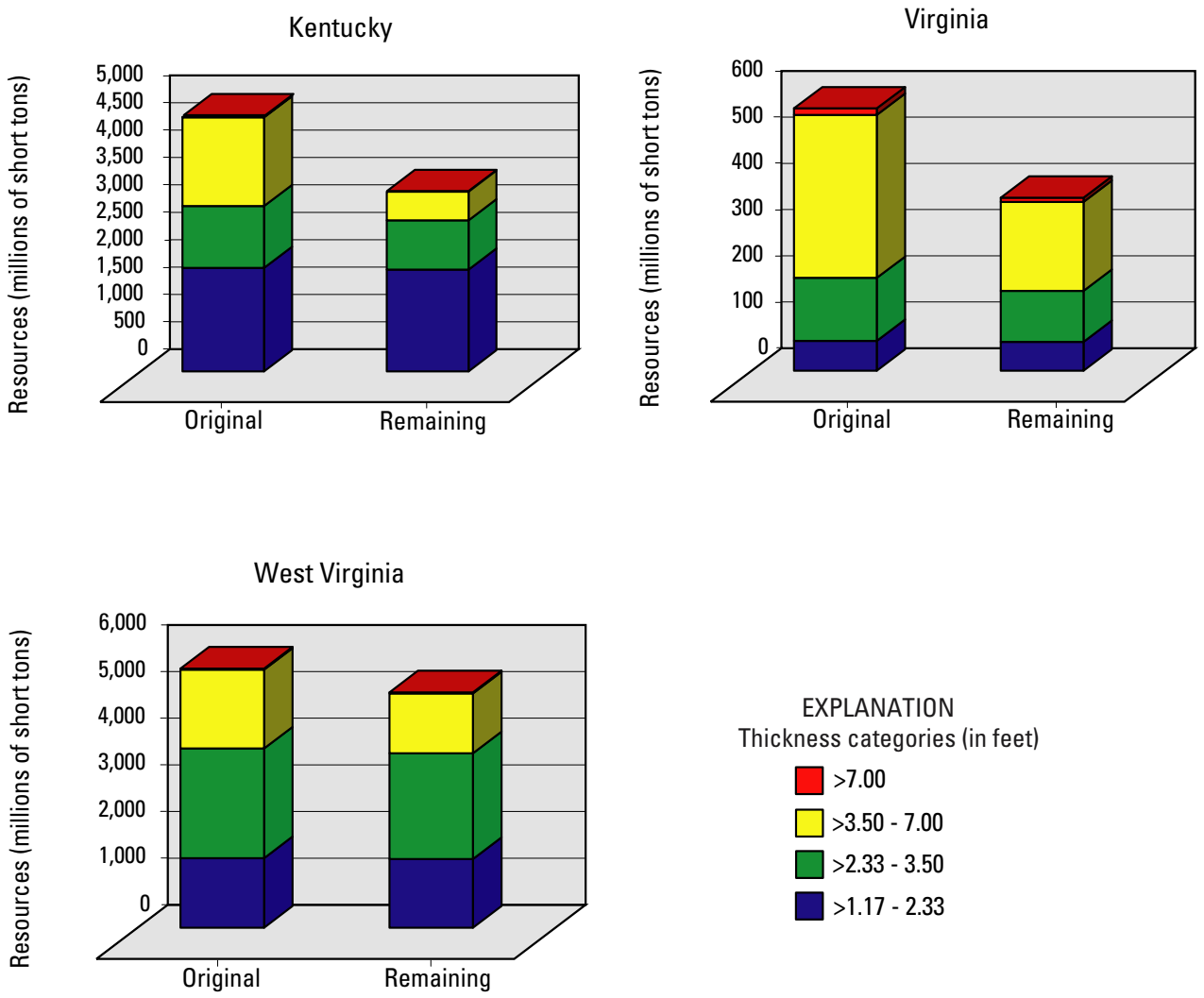

Figure 20. Bar graphs showing original and remaining Pond Creek coal zone resources (millions of short tons), by State and by USGS thickness categories. Note that a large percentage of the Pond Creek coal zone that is thicker than 3.5 ft has been mined. The majority of remaining Pond Creek coal is in the 1.17- to 3.5-ft category.

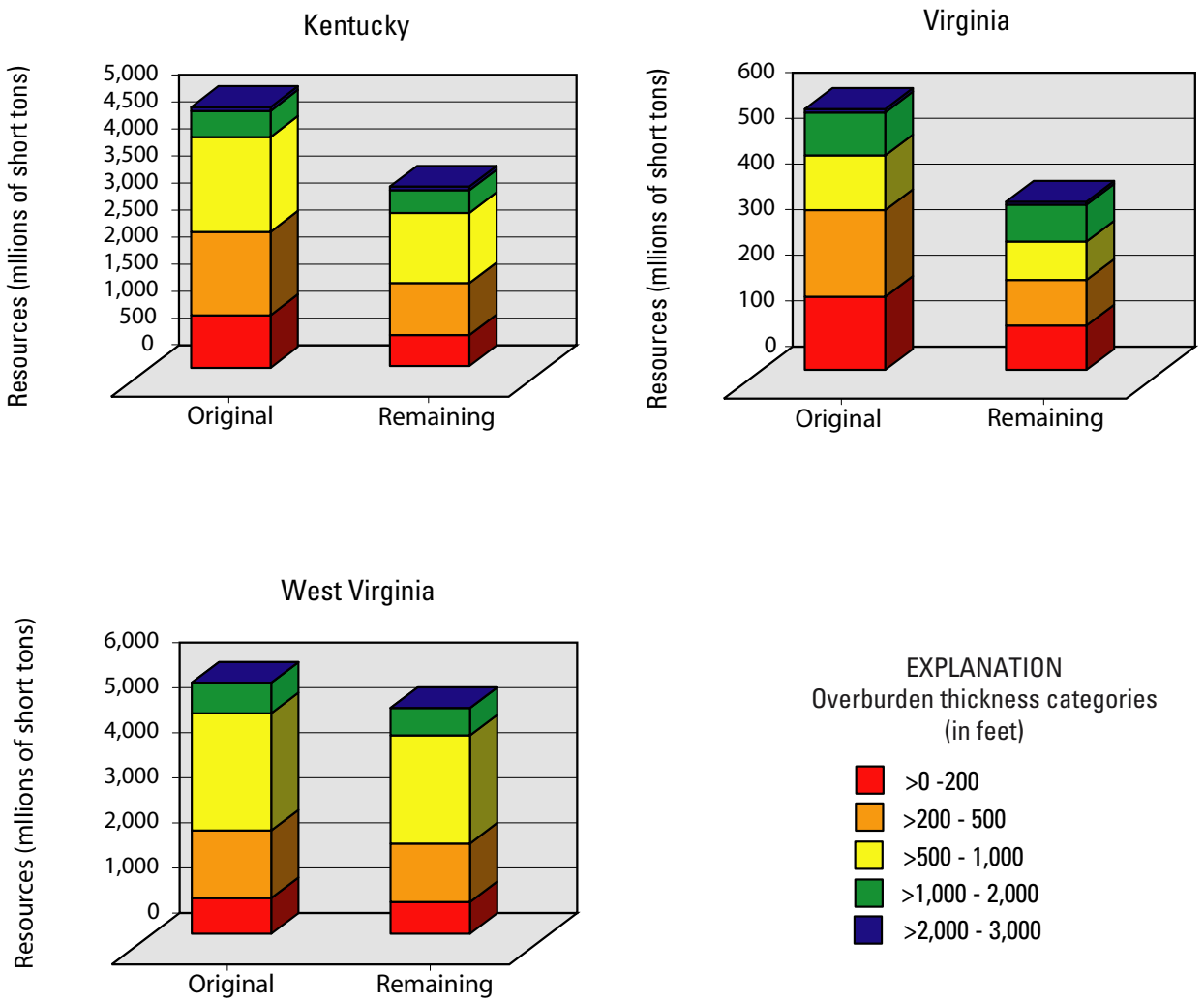

Figure 21. Bar graphs showing original and remaining Pond Creek coal zone resources (millions of short tons), by State and by USGS overburden thickness categories. Although the deepest overburden category is classified as 3,000 ft, the greatest overburden thickness actually is 2,553 ft and is in Harlan County, Ky.

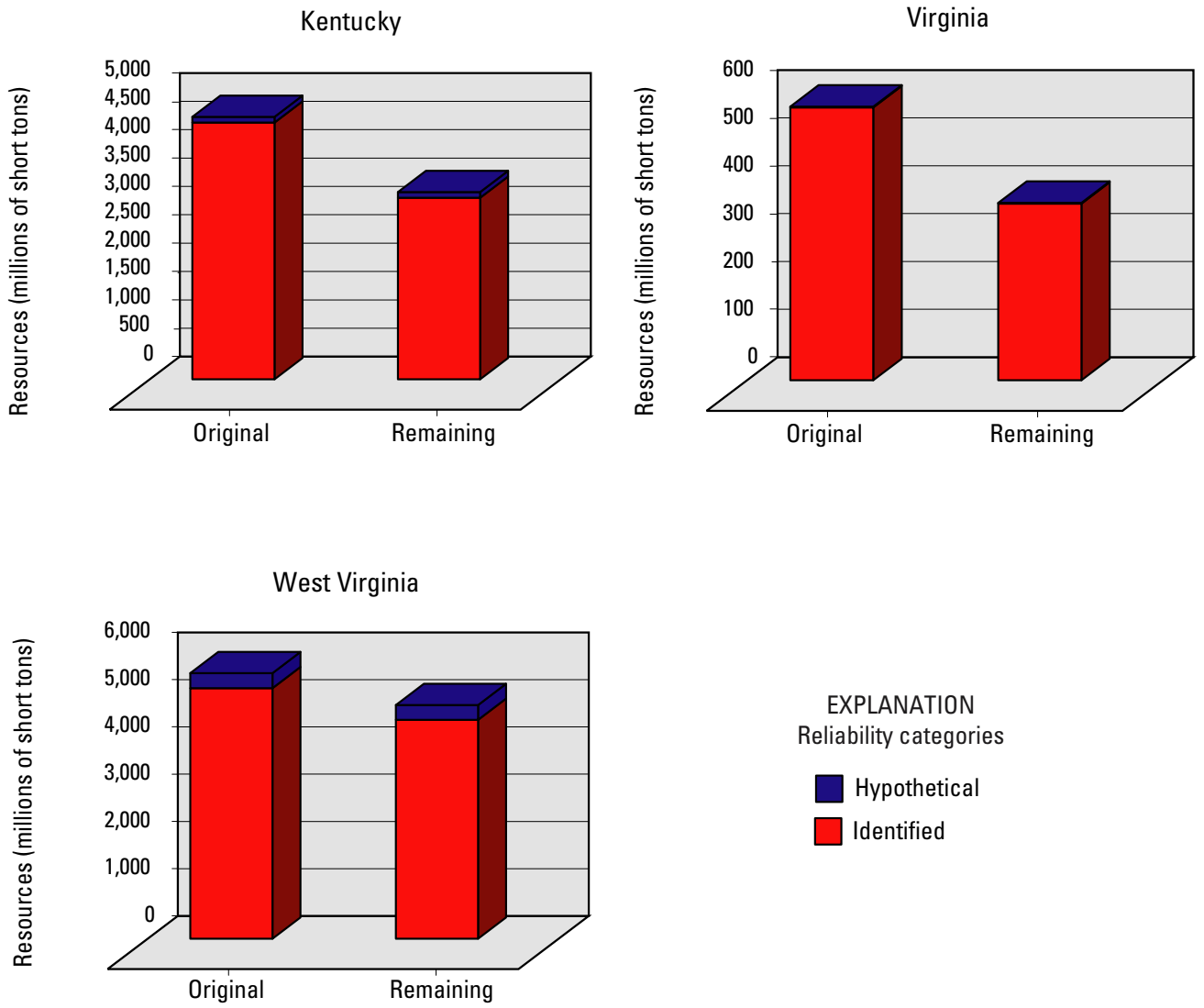

Figure 22. Bar graphs showing original and remaining Pond Creek coal zone resources (millions of short tons), by State and by USGS reliability categories. The majority of resources are identified (located within 3 mi of a thickness measurement point). Hypothetical resources are beyond 3 miles of a thickness measurement.

the metadata file in Appendix 8. References for the Pond Creek geochemical database are in Appendix 9.

All 297 of the analyses in the geochemical database for the Pond Creek coal zone (Appendix 7) are publicly available and located by latitude and longitude (shown in part A of figs. 23–25, 27, 29–41). County mean data are shown in part B of the same figures. Statistical parameters (means, ranges, standard deviations, and number of analyses) are shown in tables 2 to 18. All analyses are on an as-received whole-coal basis. Data for ash yield and sulfur content are classified into categories of low, medium, and high (figs. 23–24) according to the criteria of Wood and others (1983). Data for sulfur dioxide (SO_2) also are classified into low, medium, and high categories (fig. 25) according to past and present Clean Air Act Amendments. Gross calorific value, total moisture content, and trace element content are classified into five data categories, or quintiles, each representing 20 percent of the data values. Because the 20-percent intervals are based on different sets of data (point data versus county means), the ranges of the 20 percent intervals will be different for each data set and each chemical parameter.

Although some scatter is evident in ash yields, sulfur contents, and gross calorific values (tables 2, 3, 5), Pond Creek coal is generally low in ash yield and sulfur content (7.24±3.98 and 1.05±0.77 weight percent, as-received whole-coal basis, respectively; tables 2, 3) and high in gross calorific value (13,540±650 Btu/lb; table 5). The Pond Creek coal zone is classified as a high-volatile A bituminous coal over most of its extent (fig. 28). Based on limited data in Lee, Wolfe, and Breathitt Counties, Ky. (fig. 5), the Pond Creek coal may decrease in apparent rank to the west (fig. 28). Because Pond Creek coal is bituminous in rank, its total moisture content tends to be relatively low, with means ranging from 2.1±0.74 weight percent (as-received whole-coal basis) in Virginia to 3.1±0.99 weight percent (as-received whole-coal basis) in Kentucky. These geochemical characteristics allow the Pond Creek coal to be blended with coals that have higher ash yields and sulfur contents in order to help meet minimum emission and combustion criteria. Although not reflected in county mean maps (figs. 23B, 24B) because samples obtained near the Pond Creek coal zone outcrop tend toward higher ash yield and sulfur contents, coal in the southeastern part of the Southwestern district of Kentucky (fig. 6) can be very low in ash yield (≤8 percent) and sulfur content (≤1 percent) (figs. 23A, 24A). This coal is locally referred to as the Blue Gem coal bed and, as discussed previously, is mined in very thin benches and sold at above-market prices to utility companies that use wet-bottom boilers. Much of the Blue Gem coal that is over 28 inches (2.3 ft thick) has been mined (fig. 42).

Sulfur-dioxide (SO_2) emission limits for coal-burning utilities are mandated under the Clean Air Act Amendments of 1990 (Public Law 101–549). Beginning in 2000, the compliance level for SO_2 emissions was cut in half, from less than or equal to 2.4 pounds of sulfur dioxide per million Btu to 1.2 pounds of sulfur dioxide per million Btu, which equates to 0.6 pounds of sulfur per million Btu. With a mean SO_2 value of 1.57±1.17 pounds per million Btu, much of the Pond Creek coal zone as mined does not meet 2000 coal compliance standards (fig. 25; table 4). However, physical coal-cleaning methods that remove mineral matter and pyrite (which is the major source of inorganic sulfur in coal) are somewhat effective in reducing the sulfur content of Pond Creek coal that is delivered to power plants. About 25 percent of Pond Creek coal that was delivered to power plants between 1989 and 1997 was compliant under the 2000 compliance levels for emissions (Attanasi, 1998).

Twelve trace elements (antimony, beryllium, cadmium, chlorine, chromium, cobalt, lead, manganese, nickel, selenium, arsenic, and mercury) that may adversely affect the environment are listed by the Clean Air Act Amendments of 1990 (Public Law 101–549). For the Pond Creek coal zone, 88 coal samples were analyzed for these 12 trace elements (figs. 30–41; tables 7–18). Of these, arsenic and mercury (figs. 40, 41; tables 17, 18) are thought to have the most adverse effects on human health.

ARSENIC AND MERCURY

In some coal, arsenic (fig. 40; table 17) most commonly occurs as small microscopic inclusions within the pyrite crystal lattice. Because most Appalachian Basin coal is physically cleaned to remove pyrite and other mineral matter, most of the arsenic also is removed from the coal before combustion. The overall mean arsenic concentration (as-received whole-coal basis) for 88 Pond Creek coal zone samples is 9.9±14 ppm. Arsenic contents tend to be highest (>10 ppm) in the Southwestern district of Kentucky (fig. 6) and in Logan County, W. Va. (fig. 5). In comparison to the Appalachian Basin coal mean of 35 ppm arsenic (Finkelman and others, 1994) and the U.S. coal mean of 24±5.5 ppm arsenic (Finkelman, 1993), the Pond Creek coal zone has a lower mean arsenic content.

Mercury (fig. 41; table 18), a known neurotoxin, can accumulate in fish as methylmercury and, therefore, be concentrated in animals that feed on them. About one-third of all U.S. mercury emissions are thought to originate from coal-fired power plants (Oswald, 2000). In the near future, the U.S. Environmental Protection Agency will decide how mercury emissions from coal-fired power plants will be regulated. The mean mercury content of the 88 Pond Creek coal zone samples is relatively low (0.11±0.10 ppm; table 18), with the highest values in Bell County, Ky., and Logan County, W. Va. (figs. 4, 41). In comparison, these values are slightly lower than the Appalachian Basin mean of 0.21 ppm (Finkelman and others, 1994) and the U.S. mean of 0.17±10 ppm (Finkelman, 1993).

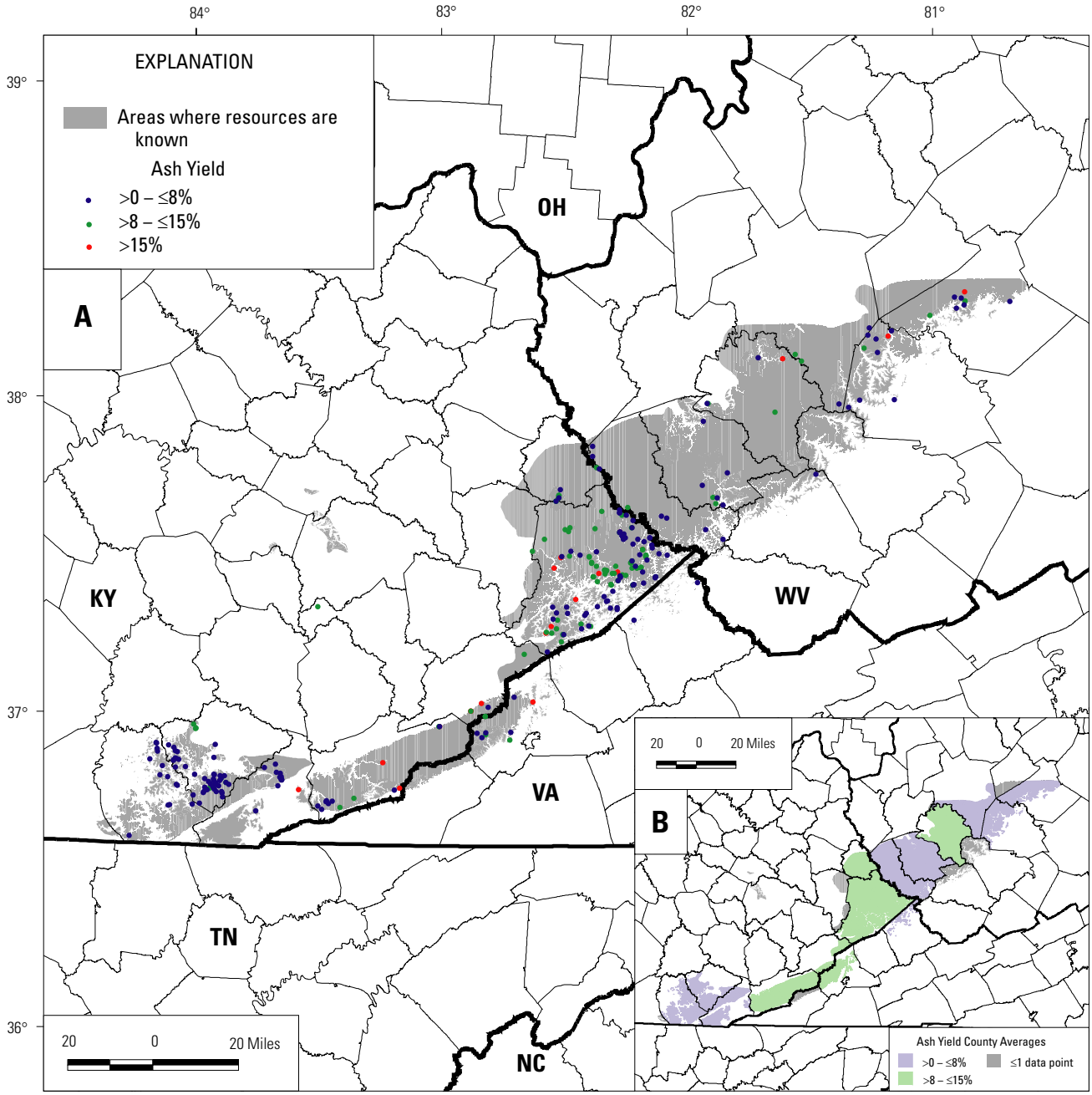

Figure 23. Map showing ash yield (weight percent, as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows ash yields of 296 geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages for ash yields, which range from 0.94 to 18.00 weight percent with a mean value of 7.24±3.98 weight percent (table 2). Ash yields are classified into low (>0 to ≤8 percent), medium (>8 to ≤15 percent), and high (>15 percent) categories as specified by Wood and others (1983). See figure 4 for county names.

Table 2. Ash yield (weight percent; American Society for Testing and Materials method) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	7.24	0.94	18.00	3.98	296
KY	na	7.19	0.94	18.00	4.12	245
VA	na	7.87	4.32	15.74	3.19	10
WV	na	7.42	2.10	16.80	3.30	41
KY	Bell	4.55	1.20	15.48	3.55	14
KY	Harlan	8.87	2.77	17.73	4.76	15
KY	Knox	4.18	1.06	12.83	3.01	48
KY	Letcher	13.17	7.81	16.54	3.83	6
KY	Martin	9.08	7.14	12.17	1.65	12
KY	Pike	8.33	1.60	18.00	3.73	135
KY	Whitley	3.34	0.94	6.29	1.41	15
VA	Buchanan	6.52	6.40	6.63	0.16	2
VA	Wise	8.21	4.32	15.74	3.53	8
WV	Boone	9.65	4.20	15.34	3.88	6
WV	Fayette	6.92	2.98	15.80	3.72	9
WV	Kanawha	7.56	4.40	11.03	3.33	3
WV	Logan	6.65	3.70	9.40	2.06	7
WV	Mingo	6.28	3.80	10.20	1.96	7
WV	Nicholas	7.95	2.10	16.80	4.35	8
WV	Wyoming	nd	7.23	7.23	nd	1

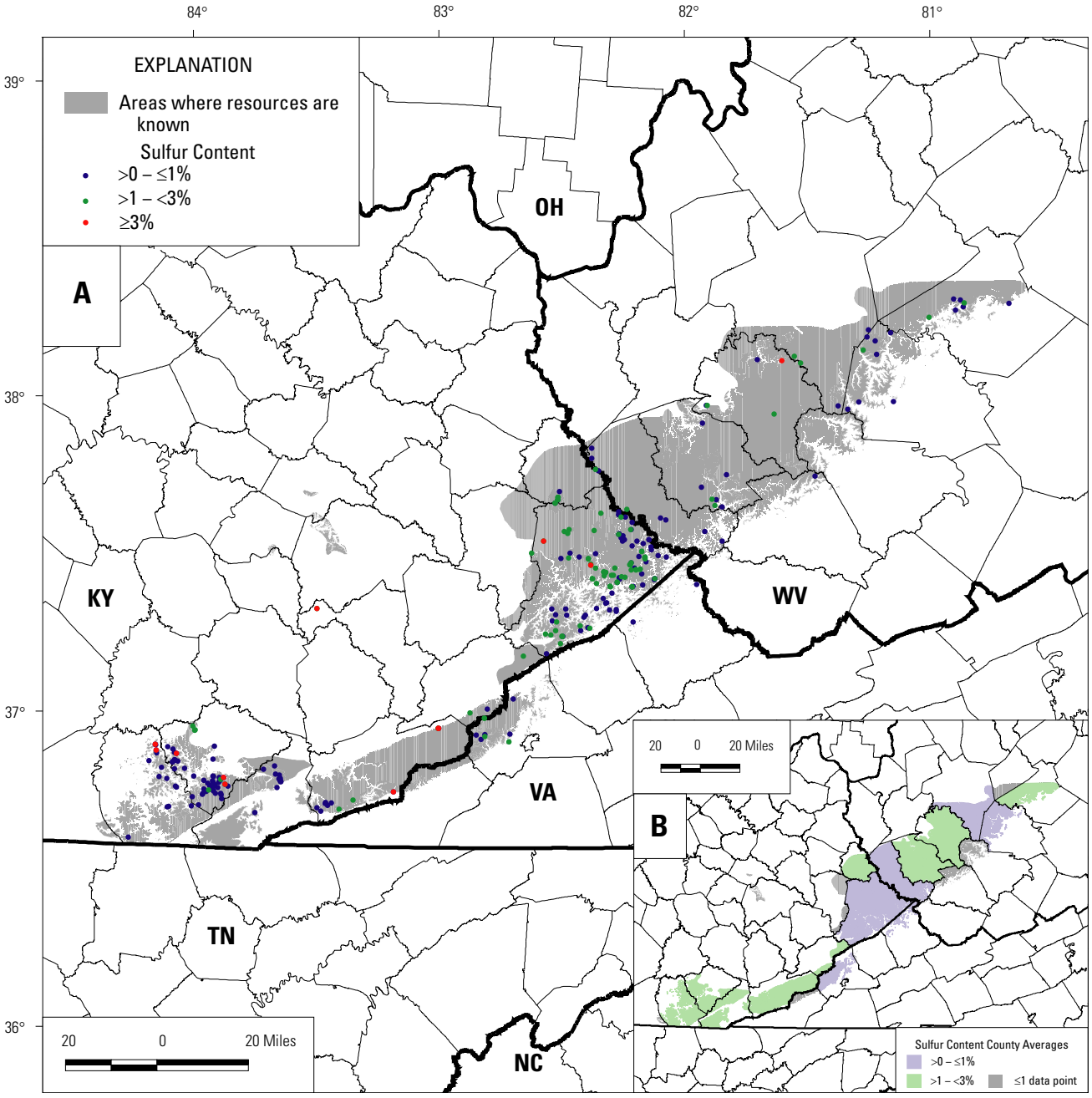

Figure 24. Maps showing sulfur content (weight percent, as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows sulfur contents of 296 samples located by latitude and longitude. Map B shows county averages for sulfur contents, which range from 0.40 to 4.64 weight percent with a mean value of 1.05±0.77 weight percent (table 3). Sulfur contents are classified into low (>0 to ≤1 percent), medium (>1 to <3 percent), and high (≥3 percent) categories as specified by Wood and others (1983). See figure 4 for county names.

Table 3. Sulfur content (weight percent; American Society for Testing and Materials method) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	1.05	0.41	4.64	0.77	296
KY	na	1.04	0.41	4.64	0.77	245
VA	na	0.88	0.58	2.49	0.57	10
WV	na	1.15	0.51	4.12	0.77	41
KY	Bell	1.14	0.67	2.40	0.48	14
KY	Harlan	2.03	0.56	3.10	0.85	15
KY	Knox	1.39	0.47	4.40	1.02	48
KY	Letcher	1.22	1.00	1.50	0.21	6
KY	Martin	1.22	0.54	1.77	0.35	12
KY	Pike	0.74	0.40	3.20	0.46	135
KY	Whitley	1.34	0.60	4.64	1.21	15
VA	Buchanan	0.71	0.61	0.80	0.13	2
VA	Wise	0.93	0.58	2.49	0.64	8
WV	Boone	2.08	0.63	4.12	1.33	6
WV	Fayette	0.87	0.60	1.70	0.34	9
WV	Kanawha	0.98	0.64	1.33	0.34	3
WV	Logan	1.17	0.60	2.30	0.59	7
WV	Mingo	0.76	0.50	0.95	0.16	7
WV	Nicholas	1.12	0.50	2.96	0.82	8
WV	Wyoming	nd	1.46	1.46	nd	1

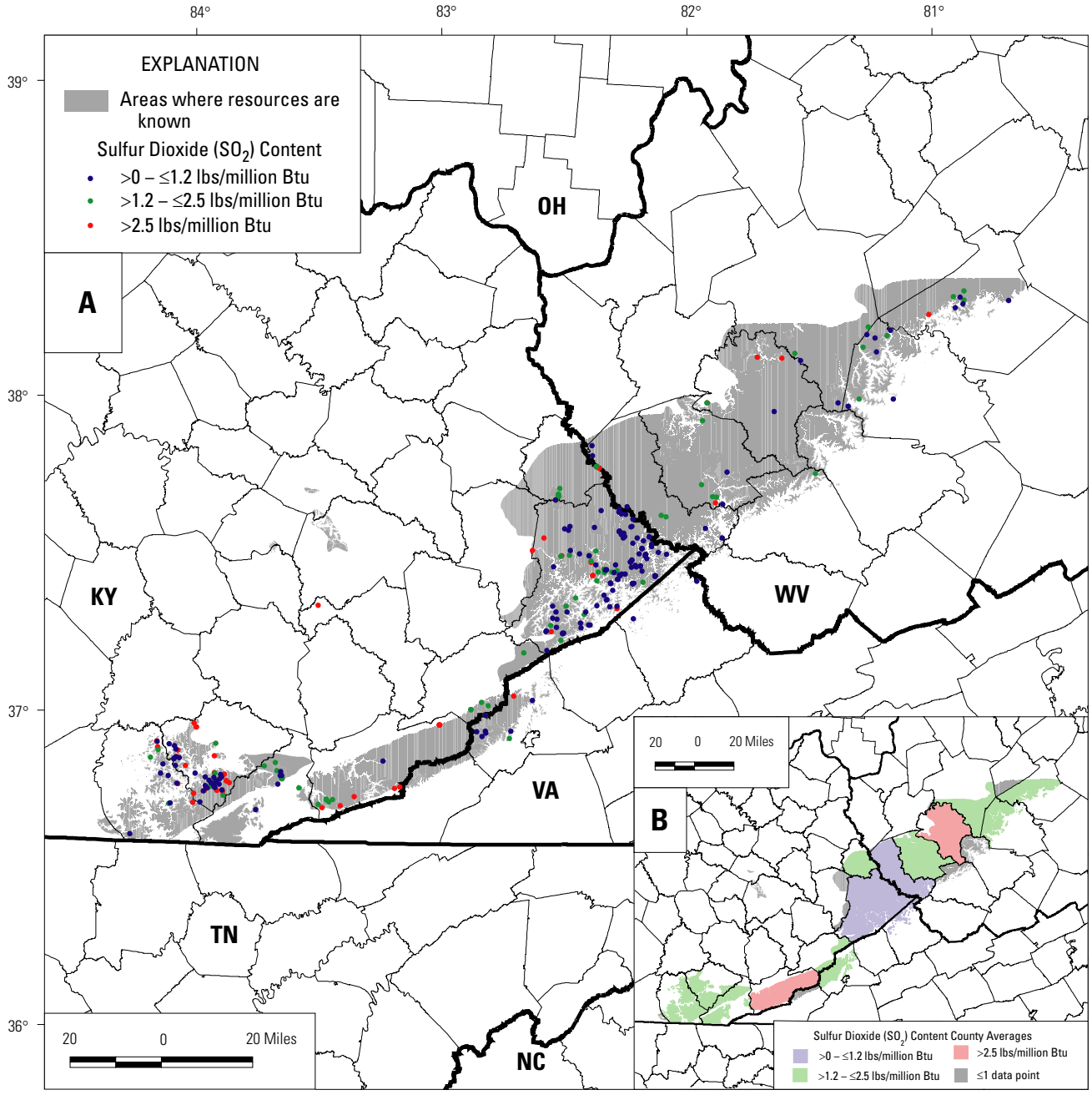

Figure 25. Maps showing sulfur-dioxide (SO_2) content (lbs/million Btu) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows SO_2 contents of 296 samples located by latitude and longitude (Appendix 7). Map B shows county averages for SO_2, which range from 0.60 to 6.90 lbs/million Btu with a mean value of 1.57±1.17 lbs/million Btu (table 4). The values are classified into three categories, low (0 to ≤1.2 lbs/million Btu), medium (>1.2 to ≤2.5 lbs/million Btu), and high (>2.5 lbs/million Btu), based on past and present U.S. Environmental Protection Agency regulations. See figure 4 for county names.

Table 4. Sulfur-dioxide (SO_2) (lbs/million Btu) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	1.57	0.60	6.90	1.17	296
KY	na	1.56	0.60	6.90	1.17	245
VA	na	1.28	0.85	3.52	0.80	10
WV	na	1.72	0.74	6.74	1.24	41
KY	Bell	1.64	0.94	3.55	0.75	14
KY	Harlan	3.08	0.91	5.11	1.37	15
KY	Knox	2.04	0.67	6.62	1.54	48
KY	Letcher	1.90	1.62	2.29	0.29	6
KY	Martin	1.87	0.84	2.67	0.52	12
KY	Pike	1.12	0.60	4.86	0.70	135
KY	Whitley	1.96	0.85	6.90	1.79	15
VA	Buchanan	1.01	0.87	1.15	0.20	2
VA	Wise	1.35	0.85	3.52	0.89	8
WV	Boone	3.25	0.95	6.74	2.20	6
WV	Fayette	1.25	0.83	2.50	0.52	9
WV	Kanawha	1.44	0.89	2.03	0.57	3
WV	Logan	1.70	0.85	3.40	0.88	7
WV	Mingo	1.11	0.77	1.34	0.20	7
WV	Nicholas	1.68	0.74	4.53	1.26	8
WV	Wyoming	nd	2.10	2.10	nd	1

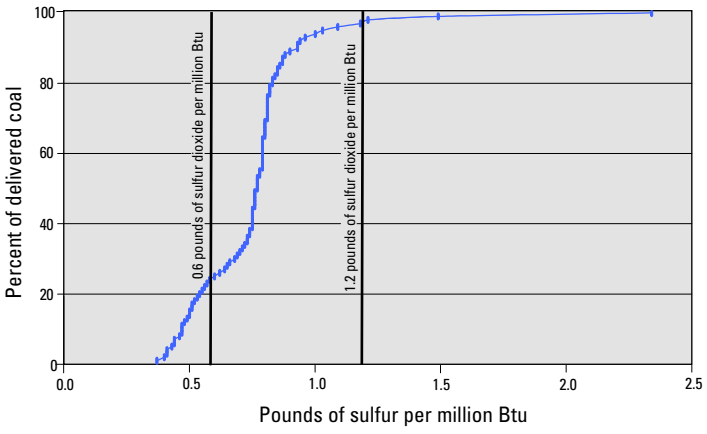

Figure 26. Graph showing sulfur in coal from the Pond Creek coal zone delivered to power plants from 1989 to 1997. During Phase I of the Clean Air Act Amendments of 1990 (Public Law 101-549), about 90 percent of the total Pond Creek coal delivered to power plants was compliant at 1.2 lbs of sulfur per million Btu (1.2 lbs of sulfur is equivalent to 2.4 lbs of SO_2 per million Btu). In Phase II, which became law in 2000, about 25 percent of the Pond Creek coal meets emission standards of 0.6 lbs of sulfur per million Btu. Data from Attanasi (1998).

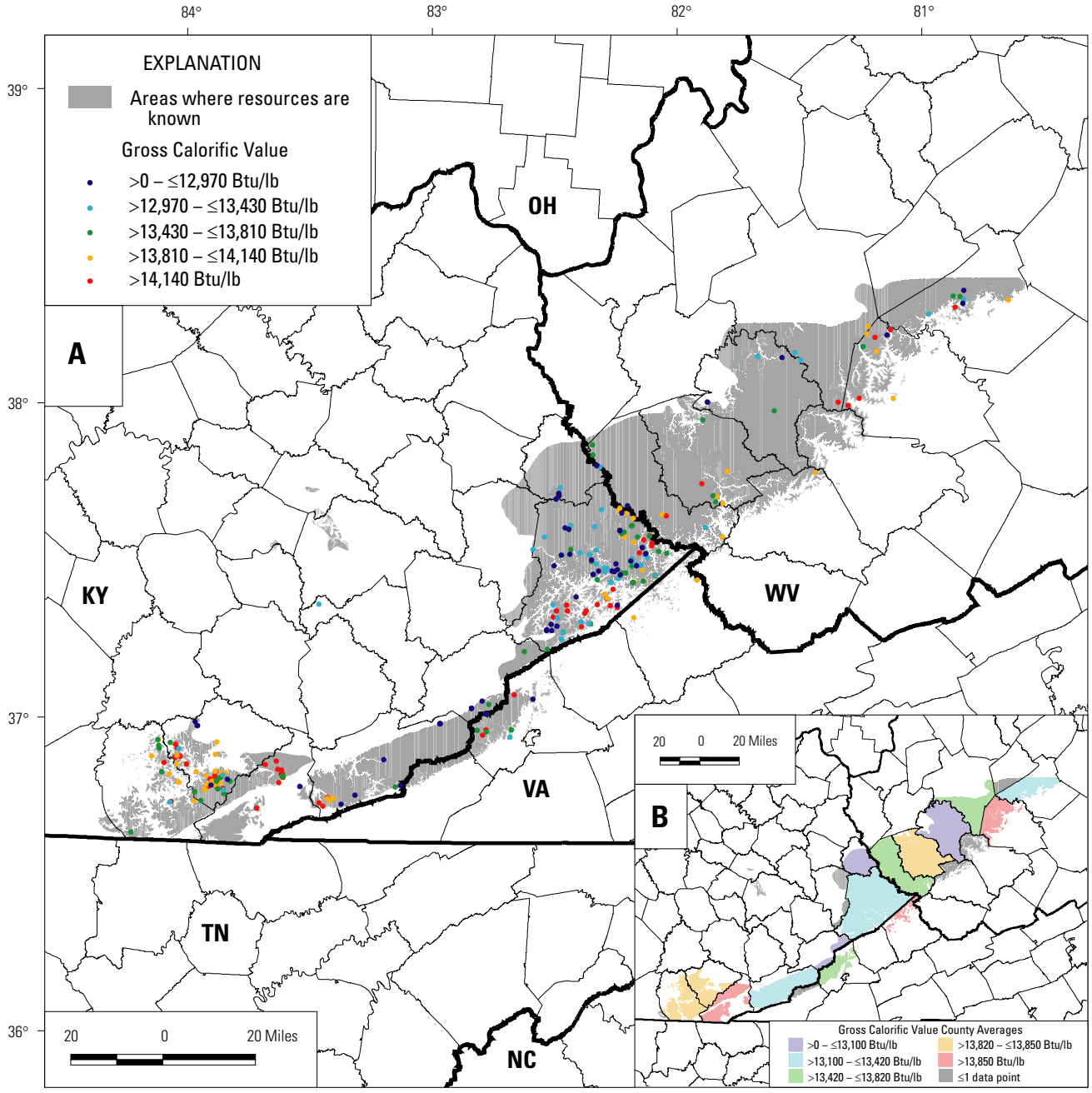

Figure 27. Maps showing gross calorific value (Btu/lb, as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows gross calorific values of 296 samples located by latitude and longitude (Appendix 7). Map B shows county averages of gross calorific values, which range from 11,290 to 14,860 Btu/lb with a mean value of 13,540±650 Btu/lb (table 5). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 5. Gross calorific value (Btu/lb; American Society for Testing and Materials method) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	13,540	11,290	14,860	650	296
KY	na	13,520	11,290	14,860	660	245
VA	na	13,740	12,430	14,520	600	10
WV	na	13,640	12,230	14,530	600	41
KY	Bell	14,080	12,360	14,860	650	14
KY	Harlan	13,310	11,770	14,430	880	15
KY	Knox	13,830	12,450	14,370	490	48
KY	Letcher	12,840	12,260	13,790	640	6
KY	Martin	12,990	12,470	13,410	260	12
KY	Pike	13,410	11,290	14,660	640	135
KY	Whitley	13,850	13,000	14,260	330	15
VA	Buchanan	14,000	13,940	14,060	90	2
VA	Wise	13,680	12,430	14,520	660	8
WV	Boone	13,100	12,230	13,810	600	6
WV	Fayette	13,940	12,470	14,510	620	9
WV	Kanawha	13,820	13,060	14,490	720	3
WV	Logan	13,840	13,510	14,210	300	7
WV	Mingo	13,630	12,970	14,180	460	7
WV	Nicholas	13,420	12,270	14,530	710	8
WV	Wyoming	nd	13,880	13,880	nd	1

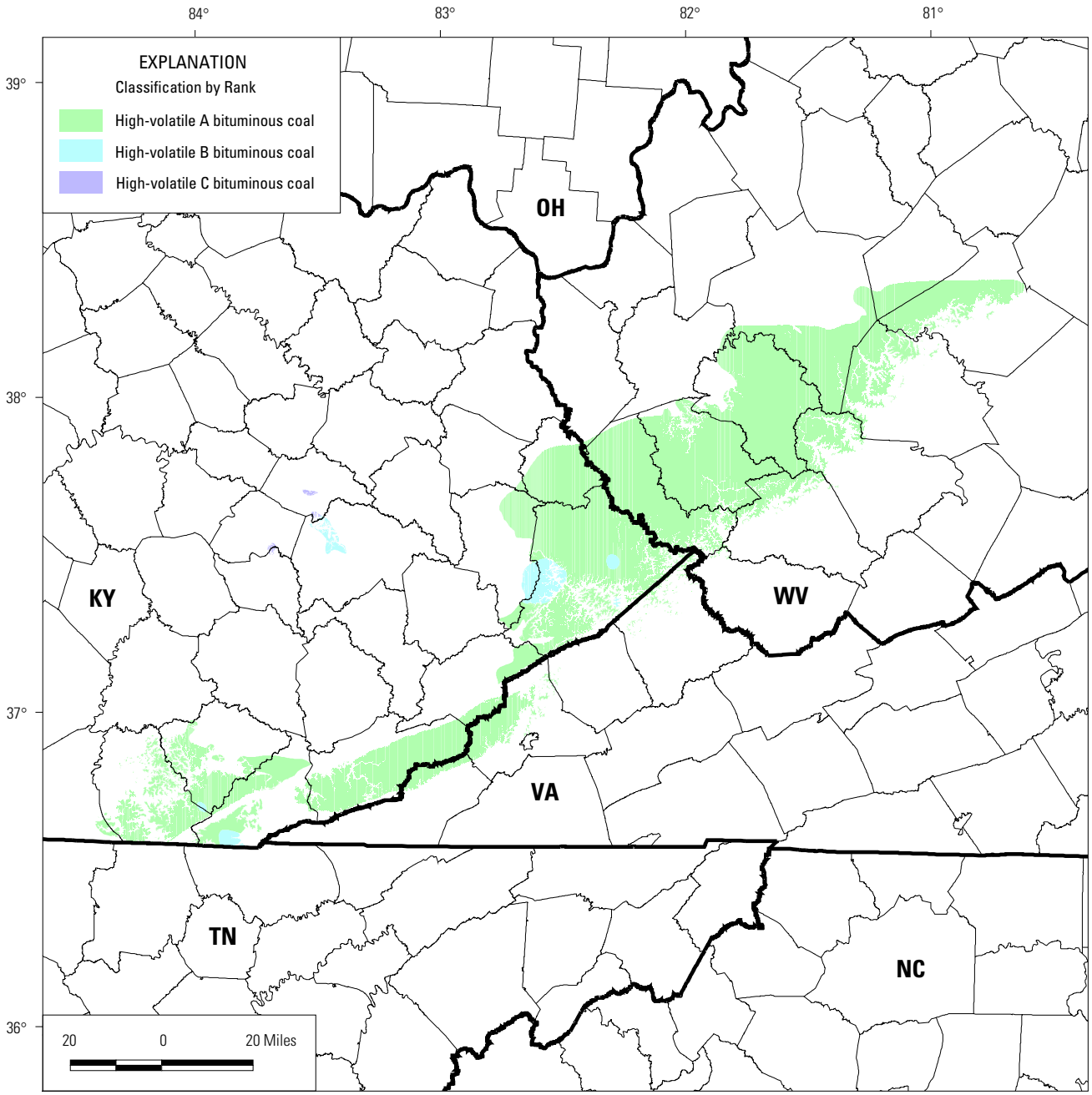

Figure 28. Map showing apparent rank of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia, based on 327 analyses. The coal shows little variation in rank and is classified as a high-volatile A bituminous coal. See figure 4 for county names.

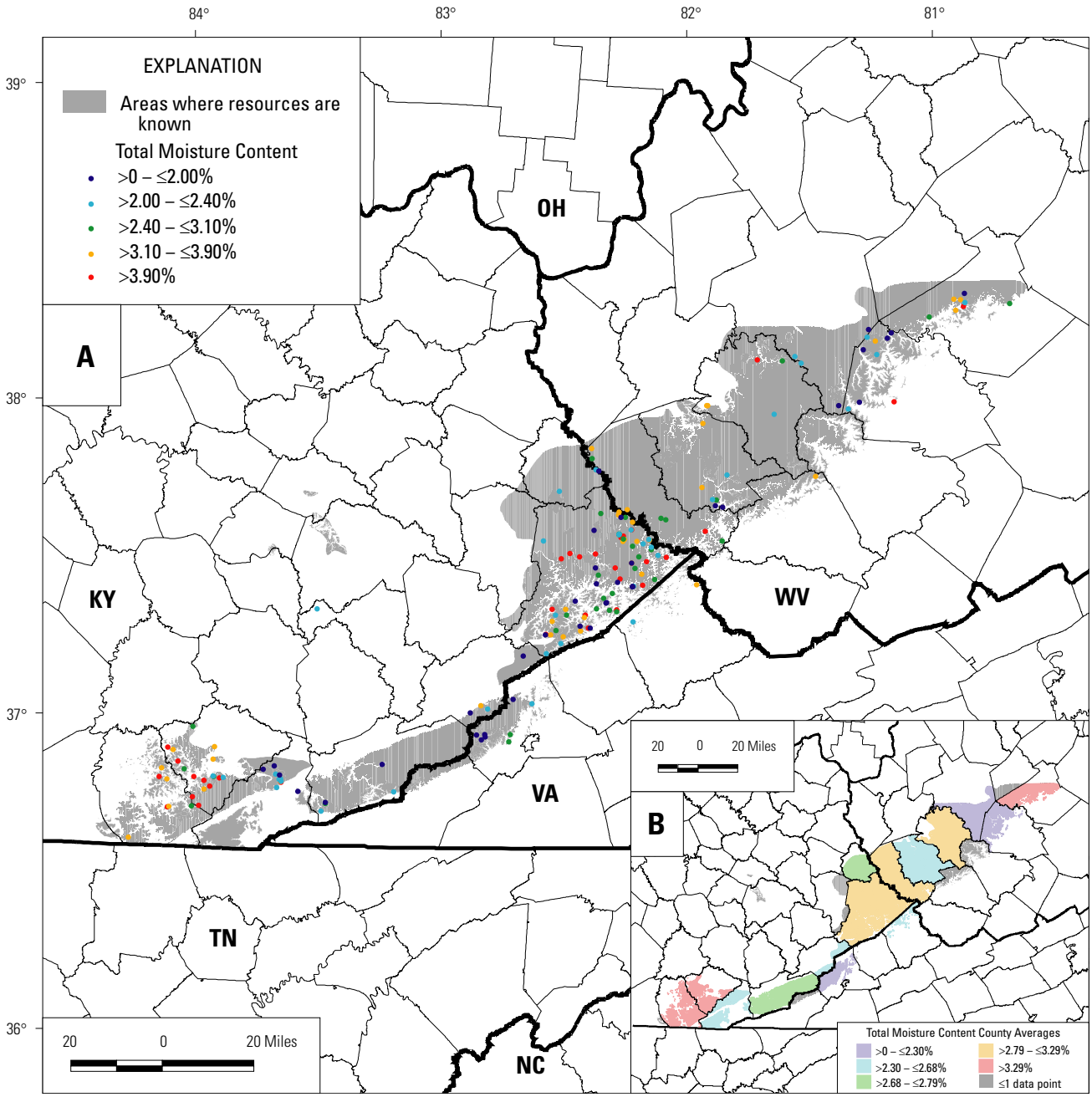

Figure 29. Maps showing total moisture content (weight percent, as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. ASTM (American Society for Testing and Materials, 1996) moisture replaced by equilibrium moisture values where available. Map A shows total moisture content for 297 samples located by latitude and longitude (Appendix 7). Map B shows county averages for total moisture contents, which range from 1.00 to 8.00 weight percent with a mean value of 3.03±1.02 weight percent (table 6). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 6. Total moisture (weight percent) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[ASTM (American Society for Testing and Materials, 1996) moisture replaced by equilibrium moisture where available. Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	3.03	1.00	8.00	1.02	297
KY	na	3.10	1.14	7.70	0.99	245
VA	na	2.10	1.21	3.30	0.74	10
WV	na	2.85	1.00	8.00	1.15	42
KY	Bell	2.68	1.46	4.55	1.08	14
KY	Harlan	2.69	1.28	3.04	0.57	15
KY	Knox	3.31	2.17	6.38	0.82	48
KY	Letcher	2.43	1.14	3.20	0.81	6
KY	Martin	2.79	1.92	3.04	0.45	12
KY	Pike	3.10	1.22	7.70	1.04	135
KY	Whitley	3.68	2.89	7.28	1.17	15
VA	Buchanan	2.68	2.05	3.30	0.88	2
VA	Wise	1.96	1.21	3.02	0.69	8
WV	Boone	3.12	2.29	4.40	0.88	6
WV	Fayette	2.30	1.00	4.20	0.94	9
WV	Kanawha	1.85	1.61	2.27	0.36	3
WV	Logan	2.61	1.80	3.80	0.69	8
WV	Mingo	3.29	2.42	4.80	0.76	7
WV	Nicholas	3.49	2.00	8.00	1.89	8
WV	Wyoming	nd	3.13	3.13	nd	1

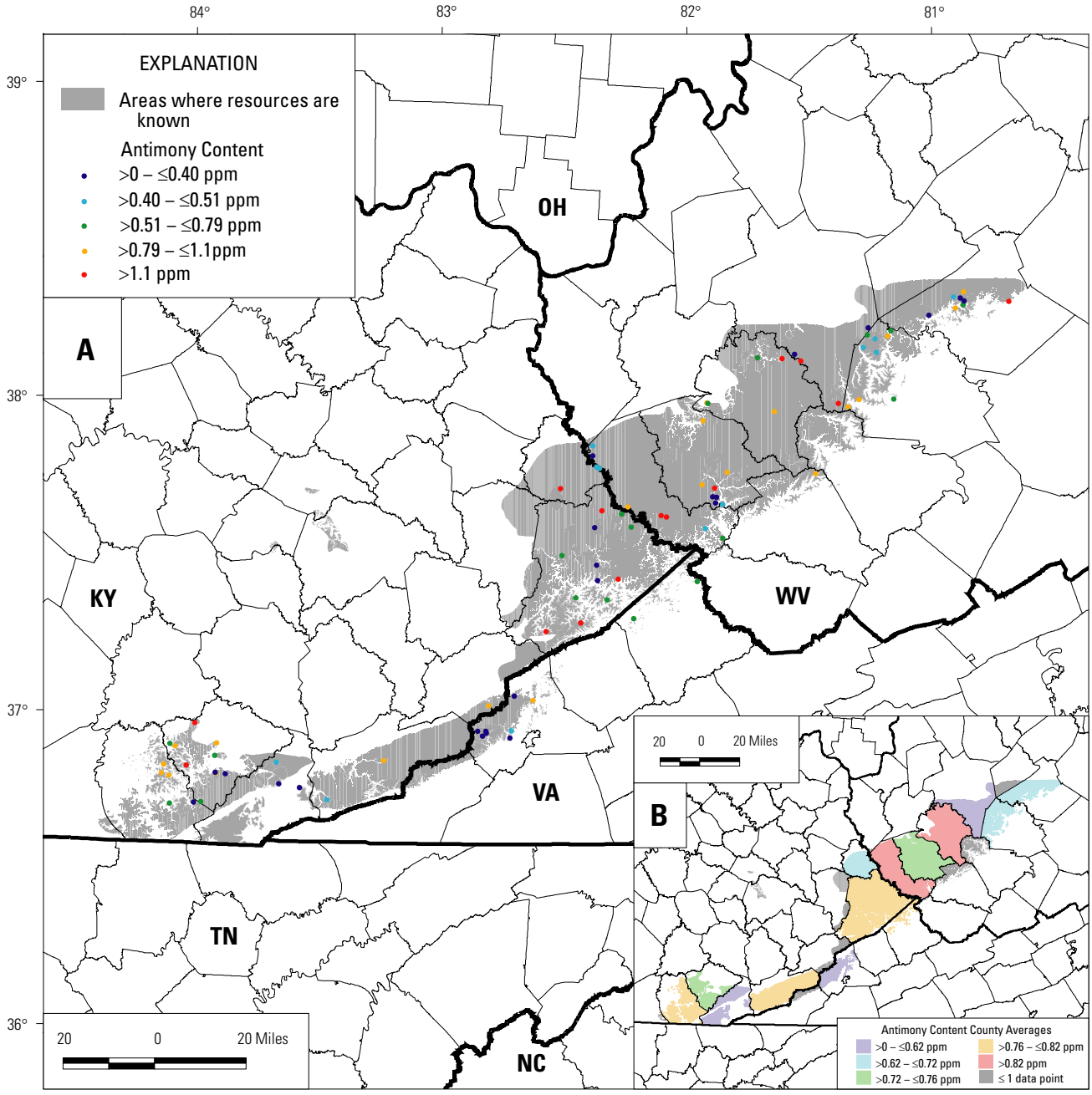

Figure 30. Map showing antimony content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows antimony contents of 88 geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages antimony for contents, which range from 0.10 to 1.6 ppm with a mean value of 0.73±0.38 ppm (table 7). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 7. Antimony content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	0.73	0.10	1.6	0.38	88
KY	na	0.76	0.10	1.6	0.38	36
VA	na	0.47	0.29	0.79	0.17	10
WV	na	0.77	0.25	1.6	0.39	42
KY	Bell	0.40	0.30	0.50	0.10	3
KY	Harlan	0.80	0.49	1.1	0.43	2
KY	Knox	0.73	0.10	1.3	0.34	10
KY	Letcher	nd	1.1	1.1	nd	1
KY	Martin	0.72	0.49	1.2	0.38	3
KY	Pike	0.82	0.19	1.6	0.49	12
KY	Whitley	0.82	0.40	1.1	0.28	5
VA	Buchanan	0.77	0.74	0.79	0.037	2
VA	Wise	0.39	0.29	0.50	0.061	8
WV	Boone	0.99	0.57	1.5	0.32	6
WV	Fayette	0.70	0.43	1.1	0.24	9
WV	Kanawha	0.62	0.32	1.2	0.50	3
WV	Logan	0.76	0.29	1.6	0.48	8
WV	Mingo	0.85	0.29	1.6	0.52	7
WV	Nicholas	0.64	0.25	1.2	0.34	8
WV	Wyoming	nd	0.89	0.89	nd	1

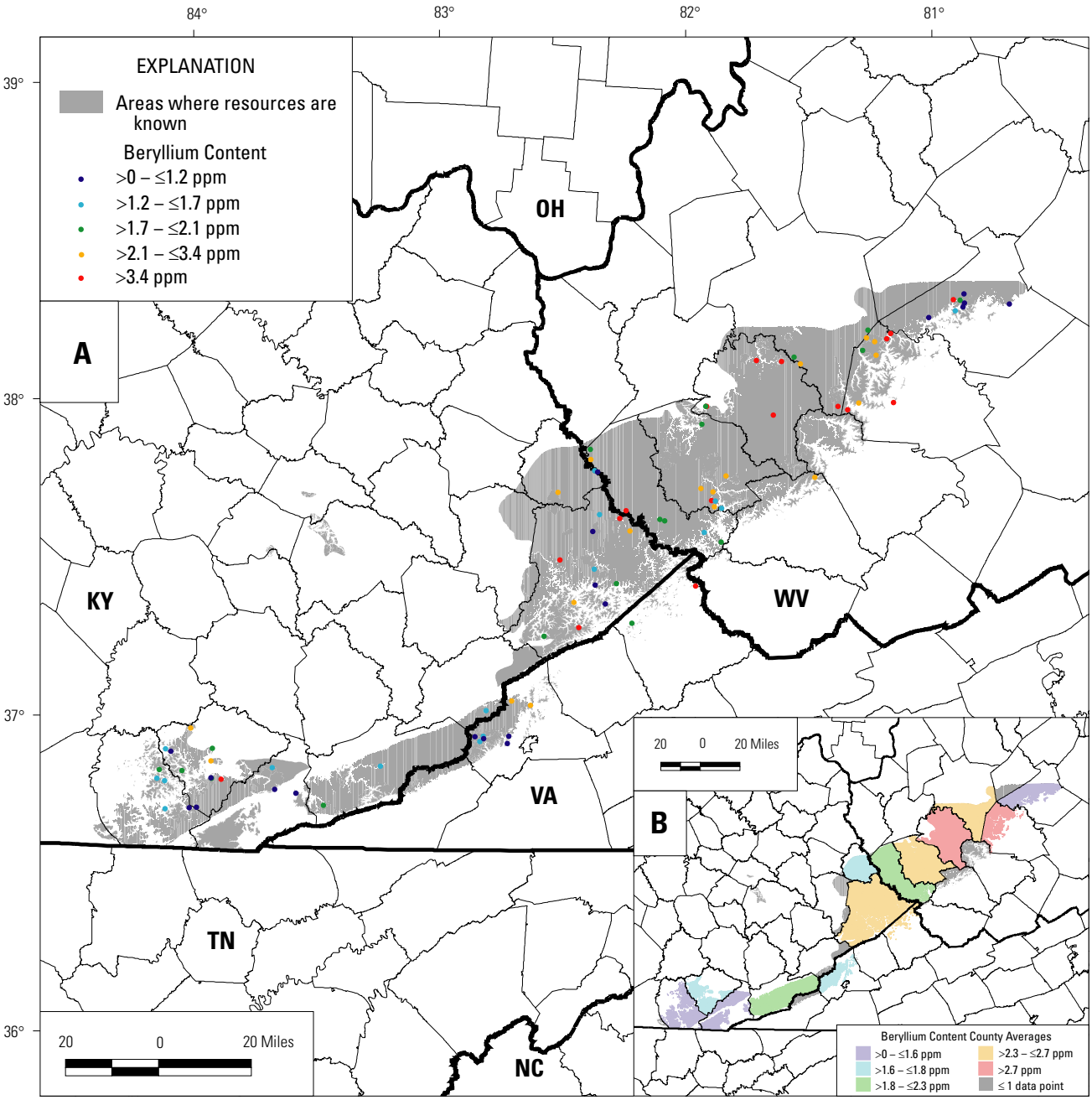

Figure 31. Map showing beryllium content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows beryllium contents for 88 geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages for beryllium contents, which range from 0.31 to 5.6 ppm with a mean value of 2.3±1.2 ppm (table 8). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 8. Beryllium content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	2.3	0.31	5.6	1.2	88
KY	na	1.9	0.54	4.7	1.0	36
VA	na	1.9	0.83	3.5	0.97	10
WV	na	2.6	0.31	5.6	1.2	42
KY	Bell	1.0	0.54	1.4	0.44	3
KY	Harlan	1.9	1.7	2.0	0.16	2
KY	Knox	1.8	0.66	3.7	0.86	10
KY	Letcher	nd	1.6	1.6	nd	1
KY	Martin	1.7	0.98	2.6	0.85	3
KY	Pike	2.4	0.71	4.7	1.3	12
KY	Whitley	1.5	0.86	2.1	0.48	5
VA	Buchanan	2.7	2.0	3.5	1.0	2
VA	Wise	1.7	0.83	3.3	0.89	8
WV	Boone	3.5	2.0	4.4	0.82	6
WV	Fayette	3.2	1.8	4.9	1.0	9
WV	Kanawha	2.5	1.8	3.7	1.1	3
WV	Logan	2.7	1.4	4.1	0.96	8
WV	Mingo	2.3	1.4	4.2	0.93	7
WV	Nicholas	1.6	0.31	5.6	1.7	8
WV	Wyoming	nd	2.8	2.8	nd	1

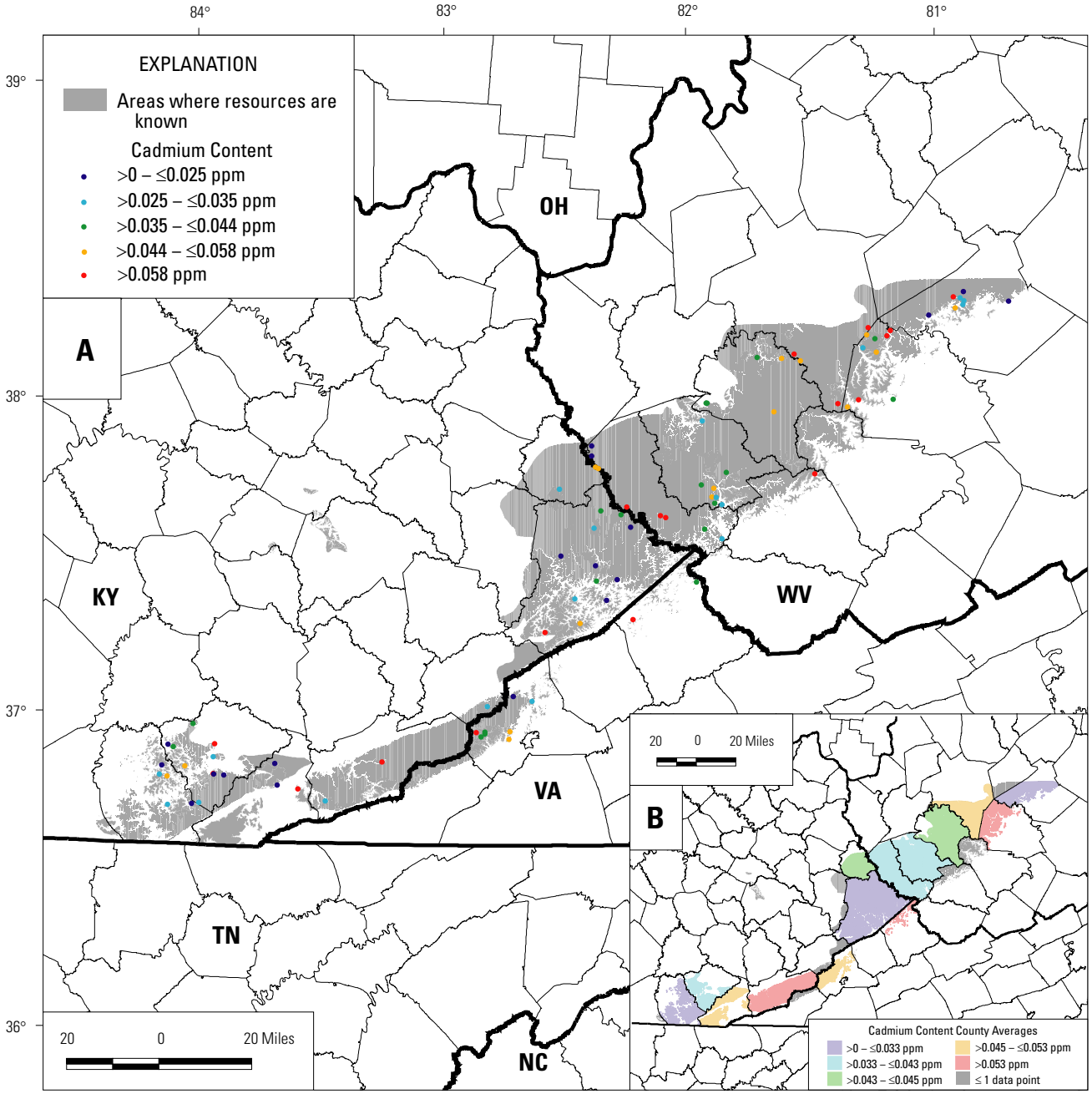

Figure 32. Maps showing cadmium content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows cadmium contents for 88 geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages for cadmium contents, which range from 0.0099 to 0.13 ppm with a mean value of 0.043±0.024 ppm (table 9). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 9. Cadmium content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	0.043	0.0099	0.13	0.024	88
KY	na	0.038	0.0099	0.13	0.025	36
VA	na	0.051	0.015	0.11	0.027	10
WV	na	0.046	0.013	0.12	0.022	42
KY	Bell	0.053	0.013	0.13	0.066	3
KY	Harlan	0.054	0.032	0.076	0.031	2
KY	Knox	0.039	0.0099	0.091	0.026	10
KY	Letcher	nd	0.028	0.028	nd	1
KY	Martin	0.044	0.034	0.053	0.0094	3
KY	Pike	0.033	0.018	0.066	0.015	12
KY	Whitley	0.028	0.010	0.047	0.015	5
VA	Buchanan	0.056	0.039	0.073	0.024	2
VA	Wise	0.050	0.015	0.11	0.029	8
WV	Boone	0.045	0.036	0.054	0.0067	6
WV	Fayette	0.061	0.033	0.12	0.029	9
WV	Kanawha	0.048	0.032	0.073	0.022	3
WV	Logan	0.039	0.026	0.058	0.0095	8
WV	Mingo	0.043	0.013	0.077	0.026	7
WV	Nicholas	0.032	0.015	0.065	0.016	8
WV	Wyoming	nd	0.089	0.089	nd	1

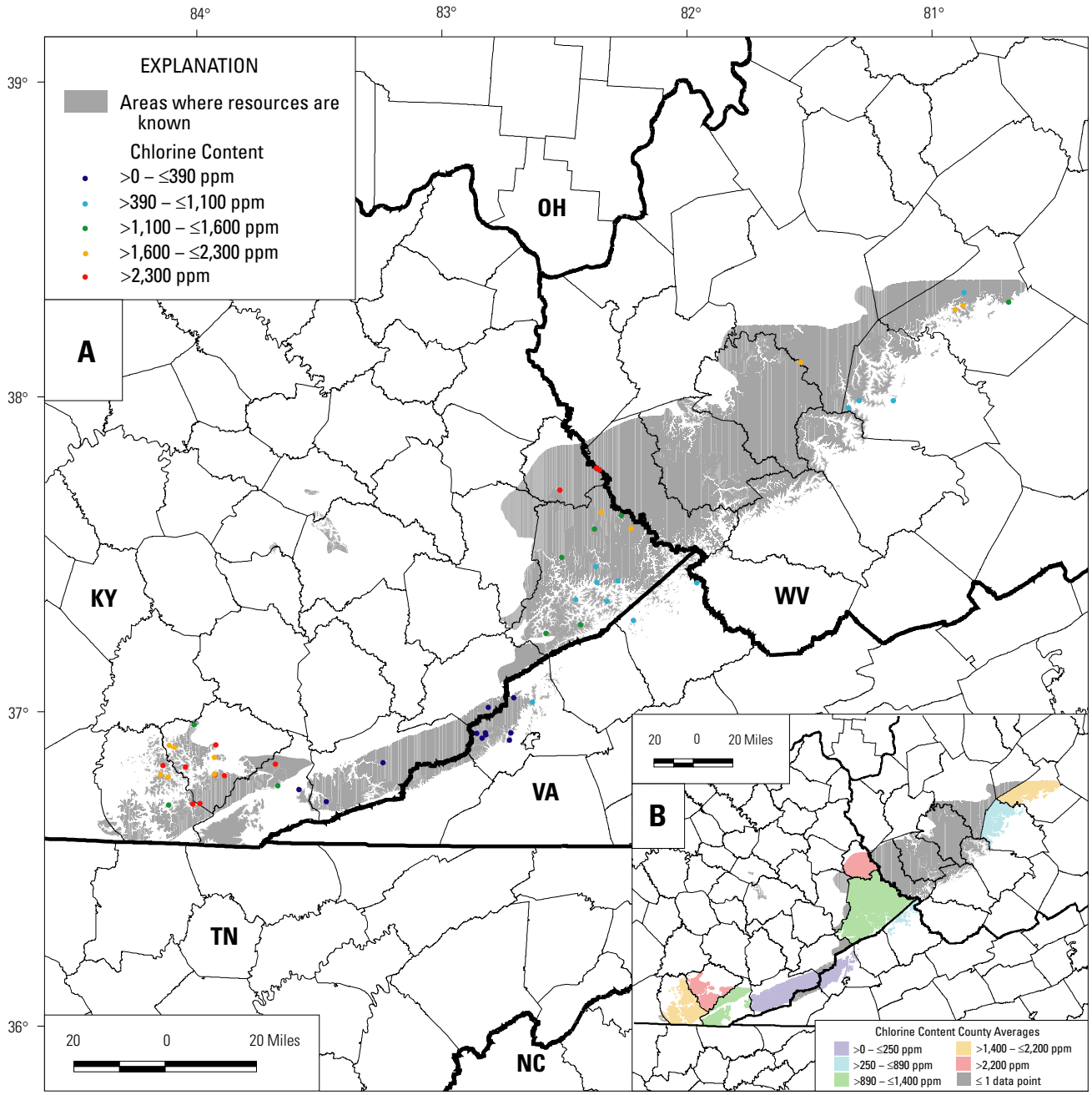

Figure 33. Maps showing chlorine content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows chlorine contents for 54 geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages for chlorine contents, which range from 50 to 3,600 ppm with a mean value of 1,500±980 ppm (table 10). The values are classified into five categories, each representing 20 percent of the data values. Chlorine contents tend to be lowest near the Pine Mountain thrust fault (fig. 2). See figure 4 for county names.

Table 10. Chlorine content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	1,500	50	3,600	980	54
KY	na	1,800	50	3,600	940	36
VA	na	380	130	1,100	310	10
WV	na	1,400	630	2,300	650	8
KY	Bell	1,400	120	2,700	1,300	3
KY	Harlan	220	50	390	240	2
KY	Knox	2,300	1,500	3,100	500	10
KY	Letcher	nd	200	200	nd	1
KY	Martin	3,400	3,300	3,600	170	3
KY	Pike	1,300	500	2,300	470	12
KY	Whitley	2,200	1,600	2,500	380	5
VA	Buchanan	890	690	1,100	280	2
VA	Wise	250	130	560	140	8
WV	Boone	nd	2,300	2,300	nd	1
WV	Fayette	860	630	1,100	260	3
WV	Nicholas	1,700	990	2,300	550	4

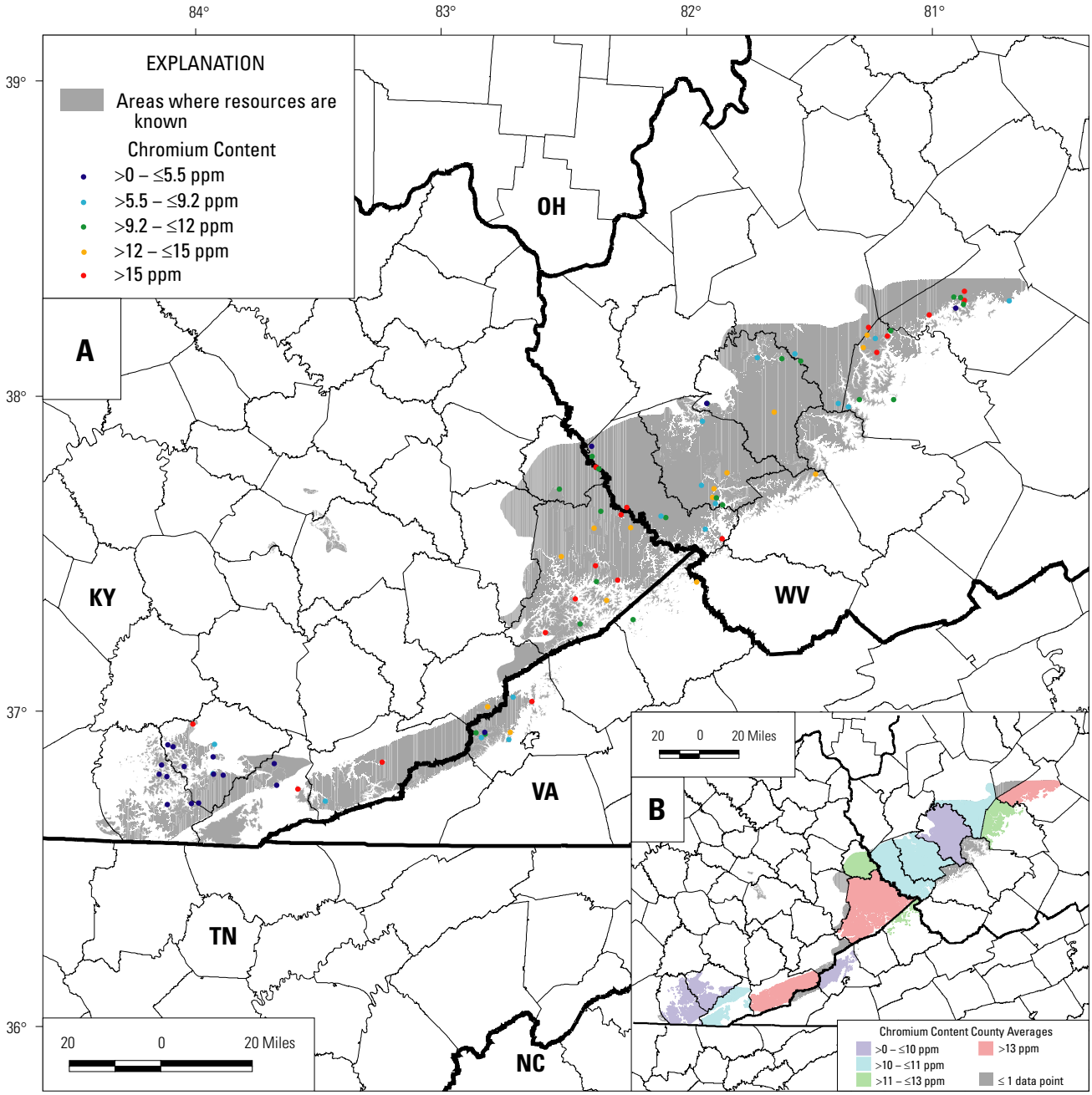

Figure 34. Maps showing chromium content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows chromium contents of 88 geochemical samples located by latitude and longitude (Appendix). Map B shows county averages for chromium contents, which range from 1.8 to 29 ppm with a mean value of 11±5.7 ppm (table 11). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 11. Chromium content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	11	1.8	29	5.7	88
KY	na	11	1.8	27	7.1	36
VA	na	11	5.3	17	3.3	10
WV	na	12	2.9	29	4.9	42
KY	Bell	11	3.1	24	12	3
KY	Harlan	17	6.0	27	15	2
KY	Knox	6.5	2.7	18	4.5	10
KY	Letcher	nd	15	15	nd	1
KY	Martin	13	11	17	3.6	3
KY	Pike	16	12	24	4.3	12
KY	Whitley	4.2	1.8	5.5	1.5	5
VA	Buchanan	12	11	13	1.3	2
VA	Wise	10	5.3	17	3.6	8
WV	Boone	10	4.2	15	3.8	6
WV	Fayette	12	7.7	16	3.2	9
WV	Kanawha	11	8.0	17	5.0	3
WV	Logan	11	5.9	15	3.3	8
WV	Mingo	11	4.5	20	5.4	7
WV	Nicholas	14	2.9	29	8.2	8
WV	Wyoming	nd	13	13	nd	1

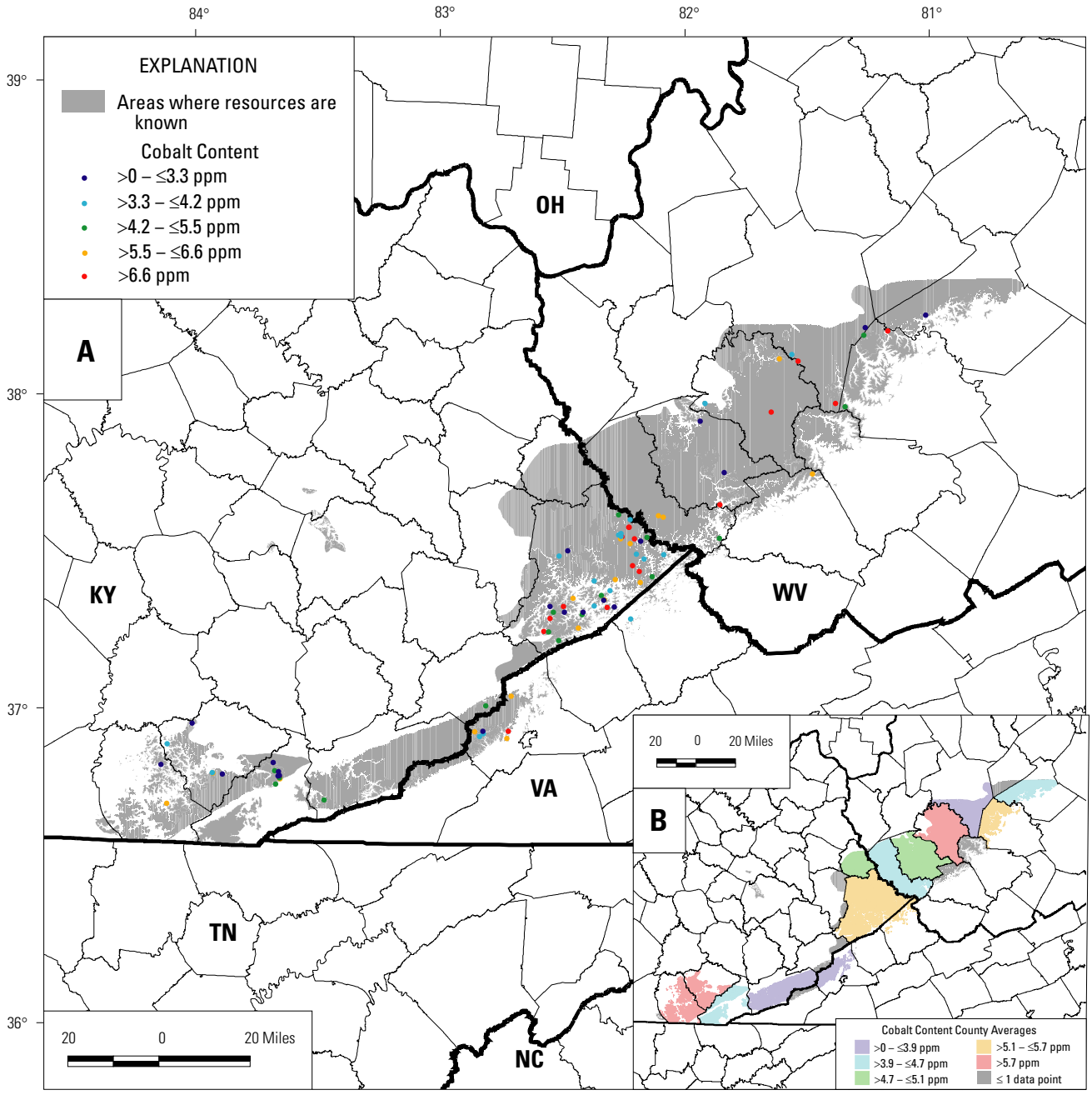

Figure 35. Maps showing cobalt content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone samples in Kentucky, Virginia, and West Virginia. Map A shows cobalt contents of 88 geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages for cobalt contents, which range from 1.5 to 13 ppm with a mean value of 5.2±2.4 ppm (table 12). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 12. Cobalt content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	5.2	1.5	13	2.4	88
KY	na	5.8	1.9	12	2.7	36
VA	na	4.2	3.0	5.8	0.89	10
WV	na	5.0	1.5	13	2.3	42
KY	Bell	4.2	1.9	6.6	2.4	3
KY	Harlan	3.5	2.3	4.8	1.8	2
KY	Knox	5.8	3.8	7.6	1.4	10
KY	Letcher	nd	5.7	5.7	nd	1
KY	Martin	5.0	3.0	8.9	3.4	3
KY	Pike	5.7	2.6	12	3.2	12
KY	Whitley	8.5	4.8	10	2.3	5
VA	Buchanan	5.5	5.2	5.8	0.43	2
VA	Wise	3.9	3.0	4.9	0.59	8
WV	Boone	6.1	2.2	8.4	2.1	6
WV	Fayette	5.7	2.0	13	4.0	9
WV	Kanawha	3.0	1.7	4.0	1.2	3
WV	Logan	5.1	3.8	5.9	0.68	8
WV	Mingo	4.4	1.5	6.0	1.7	7
WV	Nicholas	4.7	3.0	7.3	1.4	8
WV	Wyoming	nd	4.2	4.2	nd	1

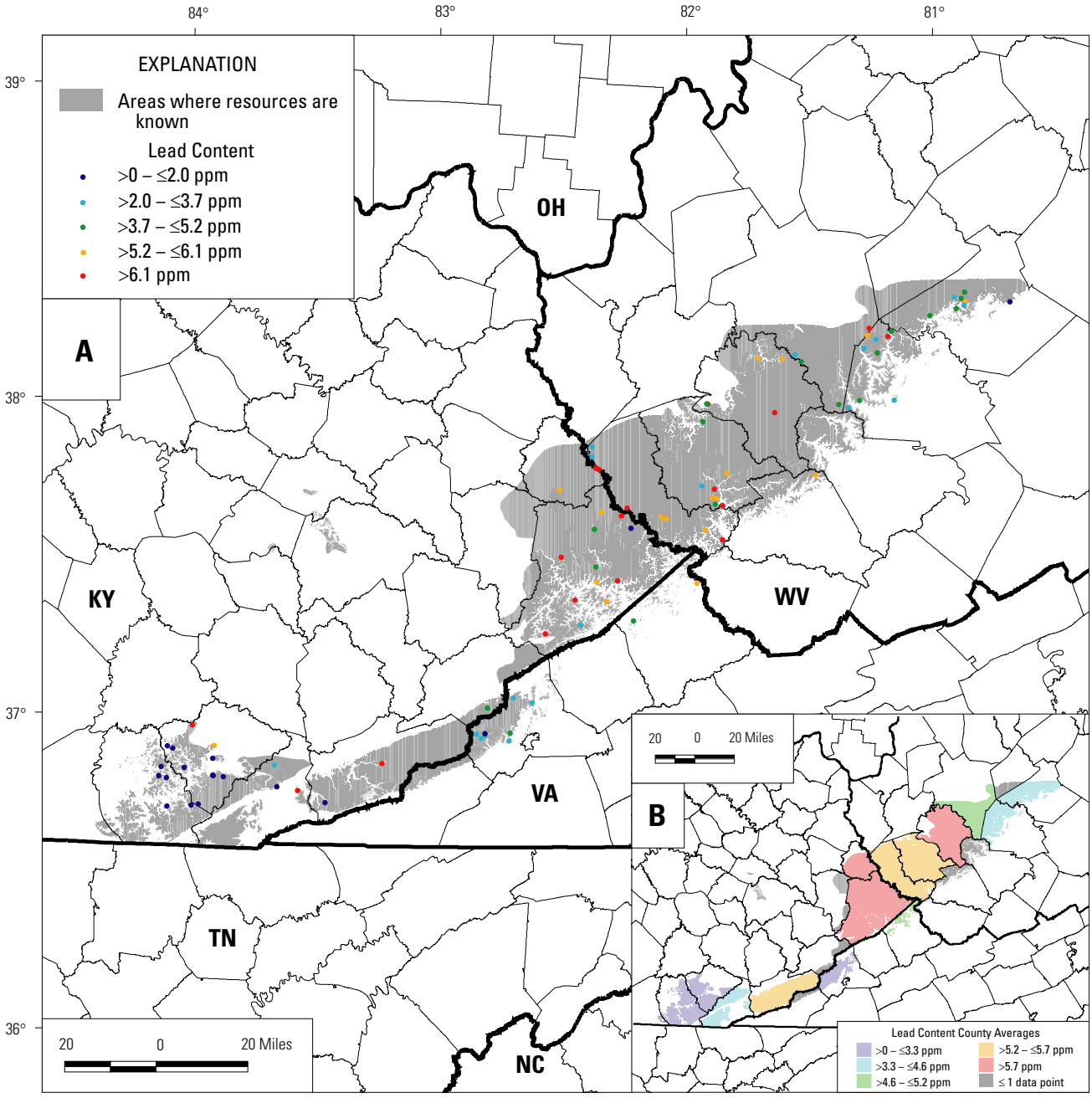

Figure 36. Maps showing lead content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows lead contents for 88 geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages for lead contents, which range from 0.48 to 10 ppm with a mean value of 4.6±2.4 ppm (table 13). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 13. Lead content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	4.6	0.48	10	2.4	88
KY	na	4.3	0.48	10	3.1	36
VA	na	3.6	2.0	6.1	1.1	10
WV	na	5.1	1.7	10	1.8	42
KY	Bell	4.3	1.3	8.7	3.9	3
KY	Harlan	5.3	1.8	8.7	4.9	2
KY	Knox	2.5	0.48	10	3.1	10
KY	Letcher	nd	5.0	5.0	nd	1
KY	Martin	7.4	5.8	9.9	2.2	3
KY	Pike	5.9	1.9	9.4	2.1	12
KY	Whitley	1.5	0.90	2.0	0.46	5
VA	Buchanan	5.0	3.9	6.1	1.5	2
VA	Wise	3.3	2.0	4.7	0.8	8
WV	Boone	5.9	3.8	8.5	1.6	6
WV	Fayette	4.6	3.0	8.7	1.9	9
WV	Kanawha	5.2	3.7	6.6	1.4	3
WV	Logan	5.7	3.3	10	2.2	8
WV	Mingo	5.6	3.1	7.9	1.9	7
WV	Nicholas	3.8	1.7	5.5	1.1	8
WV	Wyoming	nd	5.9	5.9	nd	1

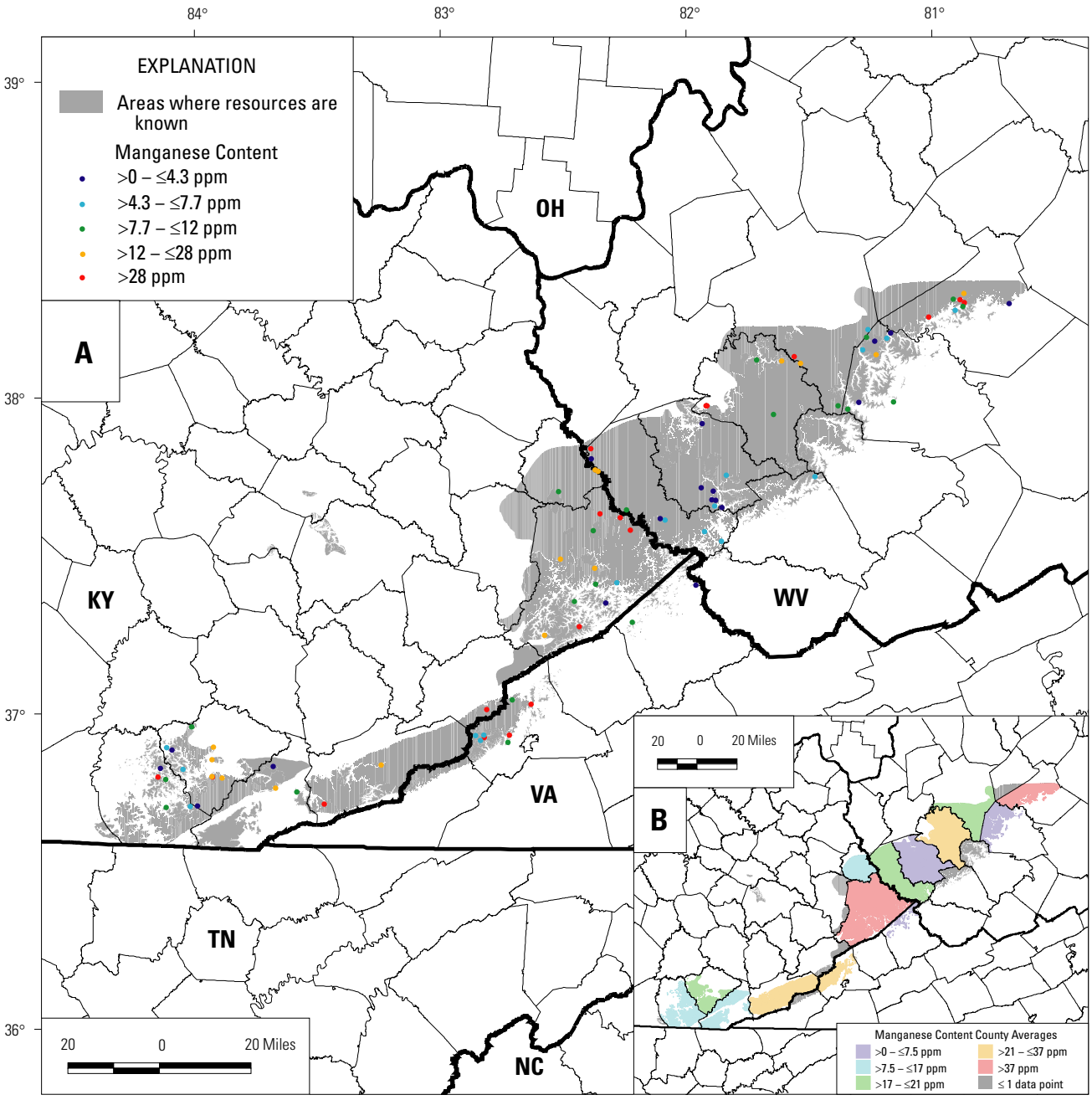

Figure 37. Maps showing manganese content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows manganese contents of 88 geochemical samples located by latitude and longitude (Appendix 7). Map B which shows county averages for manganese contents, which range from 2.0 to 180 ppm with a mean value of 23±34 ppm (table 14). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 14. Manganese content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	23	2.0	180	34	88
KY	na	27	3.2	180	40	36
VA	na	20	3.8	62	22	10
WV	na	20	2.0	160	32	42
KY	Bell	11	3.8	21	9.0	3
KY	Harlan	37	16	59	31	2
KY	Knox	20	3.8	99	28	10
KY	Letcher	nd	39	39	nd	1
KY	Martin	17	12	25	7.1	3
KY	Pike	42	3.2	180	61	12
KY	Whitley	15	4.3	45	17	5
VA	Buchanan	7.1	3.8	10	4.7	2
VA	Wise	24	5.6	62	23	8
WV	Boone	37	11	81	29	6
WV	Fayette	7.5	2.0	14	4.1	9
WV	Kanawha	21	6.5	47	22	3
WV	Logan	4.4	2.2	7.7	2.2	8
WV	Mingo	21	3.5	110	40	7
WV	Nicholas	40	2.1	160	53	8
WV	Wyoming	nd	6.8	6.8	nd	1

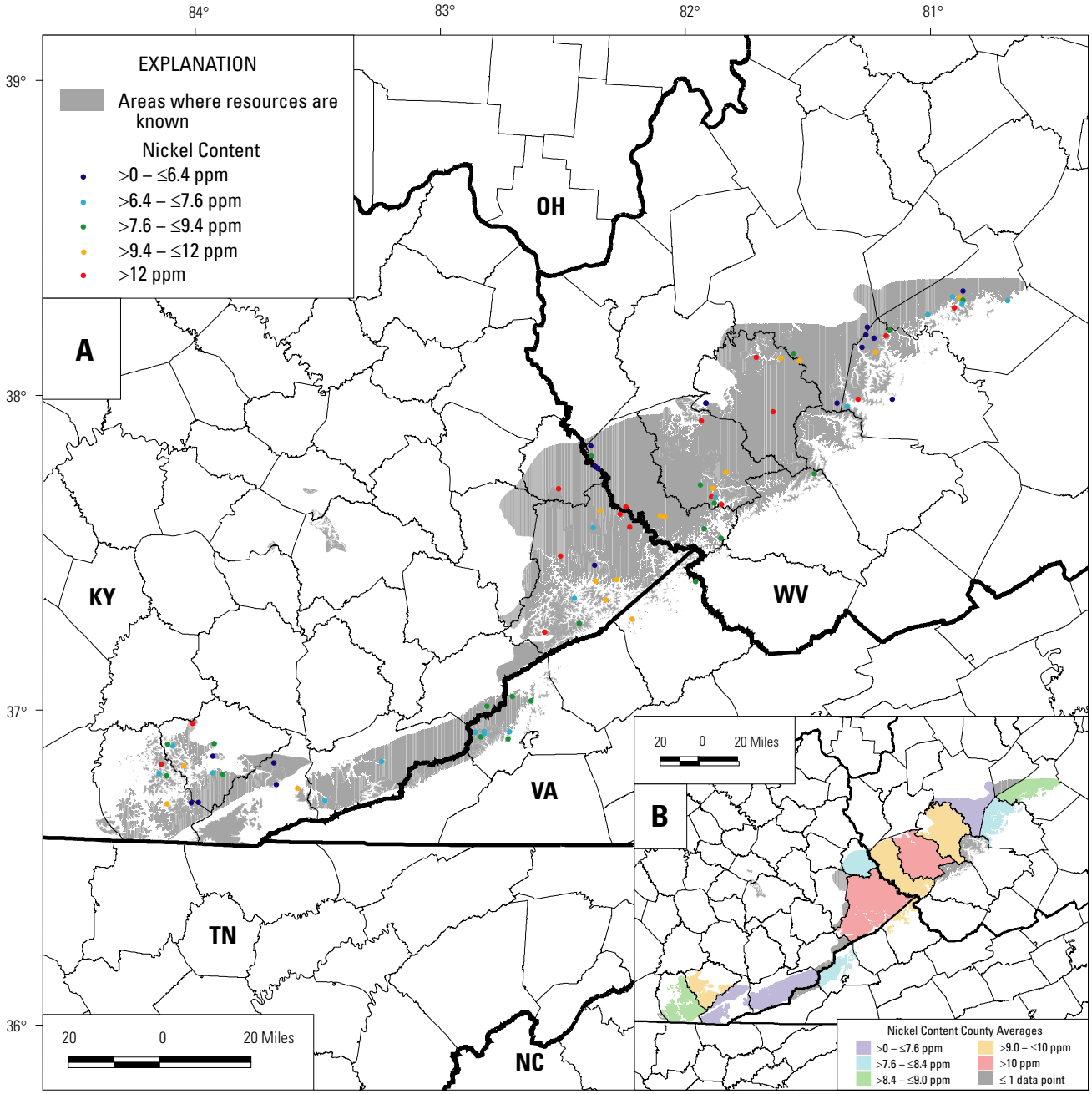

Figure 38. Maps showing nickel content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal samples zone in Kentucky, Virginia, and West Virginia. Map A shows nickel contents of 88 geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages for nickel contents, which range from 3.0 to 22 ppm with a mean value of 9.2±3.9 ppm (table 15). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 15. Nickel content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	9.2	3.0	22	3.9	88
KY	na	9.4	3.1	22	4.1	36
VA	na	8.2	6.6	11	1.4	10
WV	na	9.4	3.0	21	4.1	42
KY	Bell	6.6	3.1	12	5.1	3
KY	Harlan	7.6	7.5	7.6	0.10	2
KY	Knox	9.3	4.5	22	4.9	10
KY	Letcher	nd	9.4	9.4	nd	1
KY	Martin	8.3	5.8	13	4.0	3
KY	Pike	11	4.2	17	4.0	12
KY	Whitley	8.6	4.6	13	3.4	5
VA	Buchanan	10	8.8	11	1.8	2
VA	Wise	7.8	6.6	9.1	0.98	8
WV	Boone	10	4.9	15	3.8	6
WV	Fayette	8.4	3.0	17	4.9	9
WV	Kanawha	6.3	4.6	8.0	1.7	3
WV	Logan	11	6.9	17	3.4	8
WV	Mingo	10	6.4	17	3.4	7
WV	Nicholas	9.0	3.0	21	5.3	8
WV	Wyoming	nd	8.9	8.9	nd	1

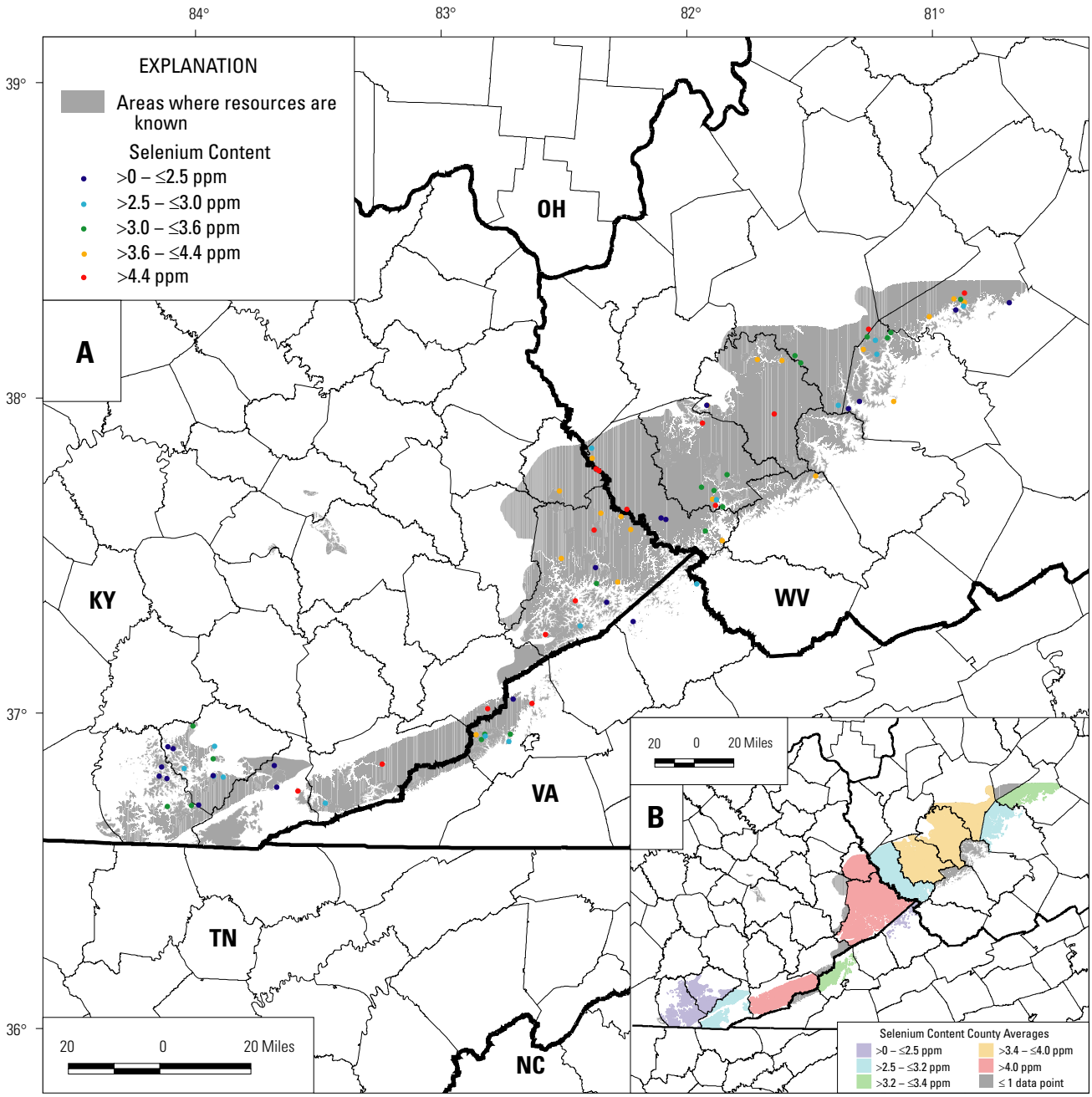

Figure 39. Maps showing selenium content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows selenium contents of 88 geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages for selenium contents, which range from 1.2 to 6.5 ppm with a mean value of 3.4±1.2 ppm. The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 16. Selenium content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	3.4	1.2	6.5	1.2	88
KY	na	3.5	1.2	6.5	1.4	36
VA	na	3.1	1.9	4.5	0.74	10
WV	na	3.5	1.2	5.7	1.1	42
KY	Bell	2.9	1.6	4.8	1.7	3
KY	Harlan	4.3	3.0	5.6	1.8	2
KY	Knox	2.5	1.3	3.4	0.72	10
KY	Letcher	nd	6.5	6.5	nd	1
KY	Martin	5.0	4.1	5.6	0.81	3
KY	Pike	4.1	2.5	5.6	1.0	12
KY	Whitley	2.4	1.2	3.6	1.1	5
VA	Buchanan	2.4	1.9	3.0	0.80	2
VA	Wise	3.3	2.3	4.5	0.67	8
WV	Boone	3.7	1.7	5.5	1.2	6
WV	Fayette	3.1	1.7	4.2	0.74	9
WV	Kanawha	4.0	3.0	5.7	1.5	3
WV	Logan	3.8	3.0	4.8	0.69	8
WV	Mingo	3.2	1.2	4.7	1.4	7
WV	Nicholas	3.4	1.7	5.5	1.3	8
WV	Wyoming	nd	4.4	4.4	nd	1

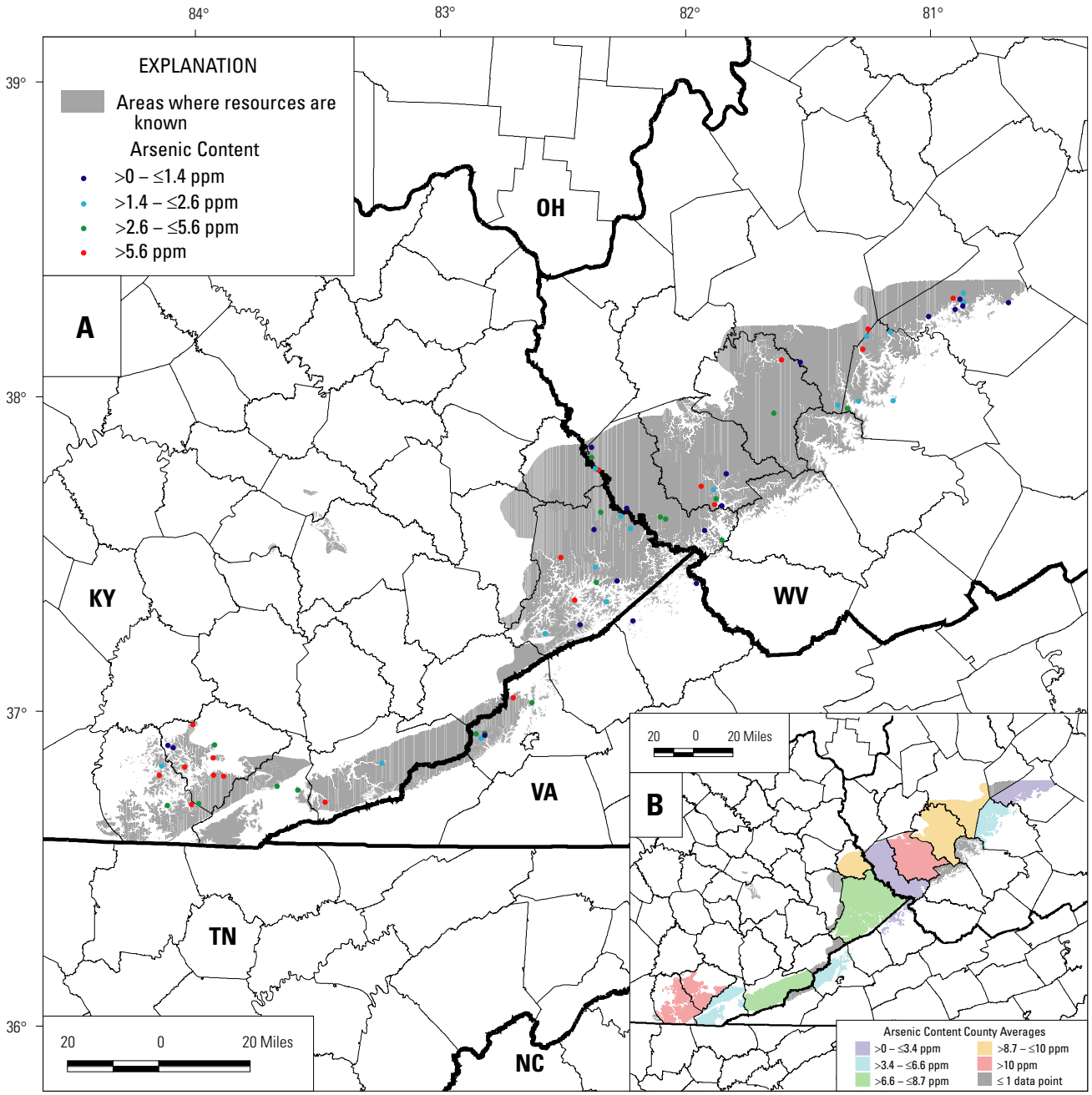

Figure 40. Maps showing arsenic content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows arsenic contents of 88 geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages for arsenic contents, which range from 0.075 to 74 ppm with a mean value of 9.9±14 ppm (table 17). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 17. Arsenic content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

State	County	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	9.9	0.075	74	14	88
KY	na	15	0.64	74	19	36
VA	na	5.5	0.89	21	6.1	10
WV	na	6.9	0.075	31	7.5	42
KY	Bell	5.4	3.5	8.4	2.7	3
KY	Harlan	8.7	2.0	15	9.5	2
KY	Knox	27	1.3	74	28	10
KY	Letcher	nd	14	14	nd	1
KY	Martin	9.1	2.6	18	8.1	3
KY	Pike	8.2	0.64	43	15	12
KY	Whitley	18	1.7	40	17	5
VA	Buchanan	0.89	0.89	0.89	0.0024	2
VA	Wise	6.6	1.4	21	6.3	8
WV	Boone	10	1.4	21	6.8	6
WV	Fayette	5.3	1.7	15	4.2	9
WV	Kanawha	10	1.7	15	7.6	3
WV	Logan	11	0.57	31	12	8
WV	Mingo	2.9	0.77	5.1	1.7	7
WV	Nicholas	3.4	0.075	19	6.2	8
WV	Wyoming	nd	13	13	nd	1

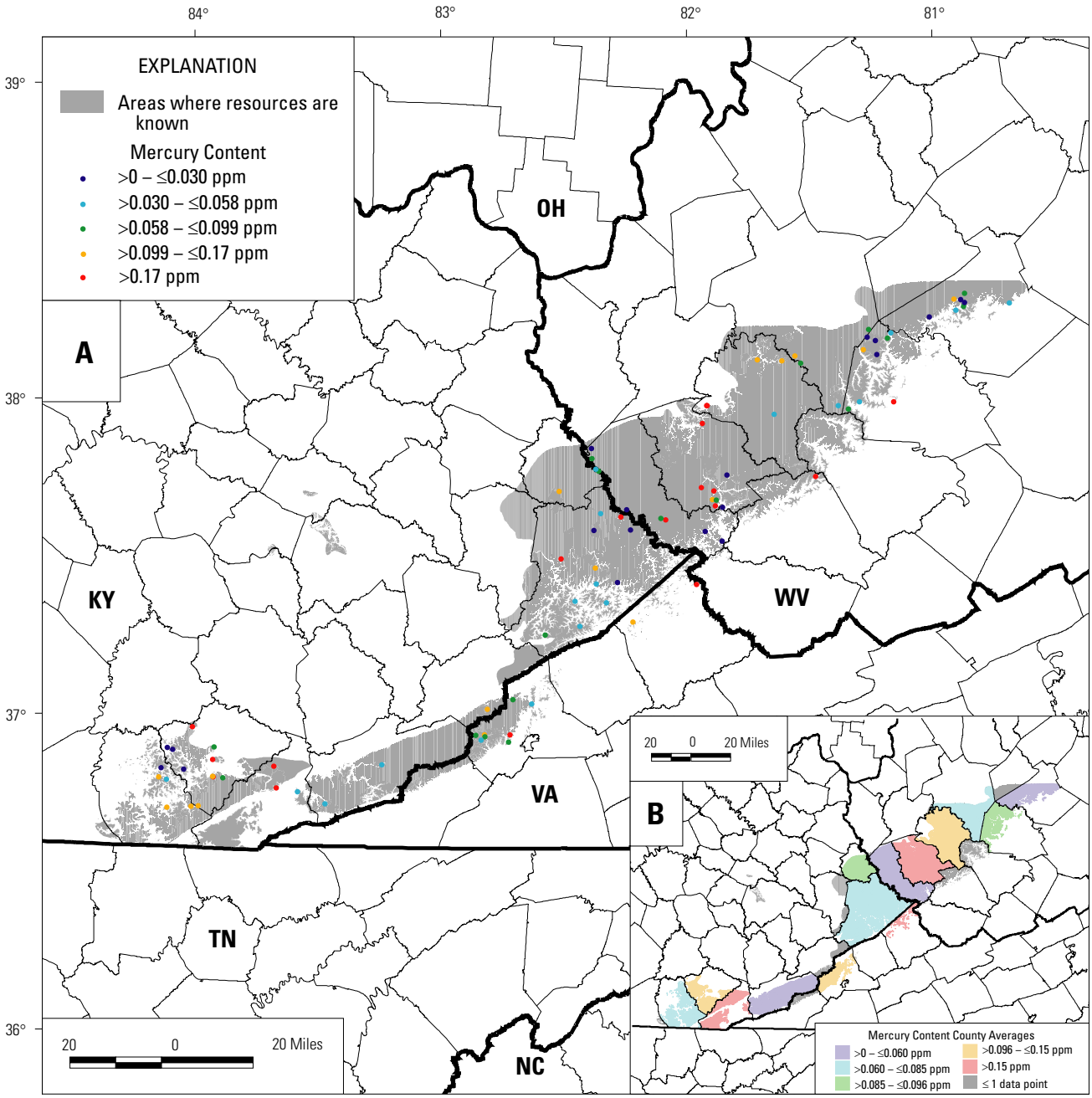

Figure 41. Maps showing mercury content (parts per million (ppm), as-received whole-coal basis) of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. Map A shows mercury contents of 88 public geochemical samples located by latitude and longitude (Appendix 7). Map B shows county averages for mercury contents, which range from 0.0048 to 0.44 ppm with a mean value of 0.11±0.10 ppm (table 18). The values are classified into five categories, each representing 20 percent of the data values. See figure 4 for county names.

Table 18. Mercury content (parts per million) means, ranges, and standard deviations for samples of the Pond Creek coal zone on an as-received whole coal-basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	0.11	0.0048	0.44	0.10	88
KY	na	0.11	0.0048	0.40	0.094	36
VA	na	0.12	0.045	0.27	0.070	10
WV	na	0.11	0.0097	0.44	0.11	42
KY	Bell	0.22	0.049	0.40	0.17	3
KY	Harlan	0.054	0.049	0.058	0.0060	2
KY	Knox	0.12	0.0048	0.35	0.11	10
KY	Letcher	nd	0.17	0.17	nd	1
KY	Martin	0.096	0.058	0.15	0.052	3
KY	Pike	0.084	0.029	0.26	0.075	12
KY	Whitley	0.085	0.0048	0.13	0.054	5
VA	Buchanan	0.17	0.15	0.19	0.027	2
VA	Wise	0.11	0.045	0.27	0.073	8
WV	Boone	0.15	0.035	0.30	0.10	6
WV	Fayette	0.093	0.0097	0.44	0.14	9
WV	Kanawha	0.084	0.043	0.12	0.038	3
WV	Logan	0.18	0.016	0.44	0.16	8
WV	Mingo	0.060	0.014	0.20	0.069	7
WV	Nicholas	0.058	0.016	0.13	0.036	8
WV	Wyoming	nd	0.21	0.21	nd	1

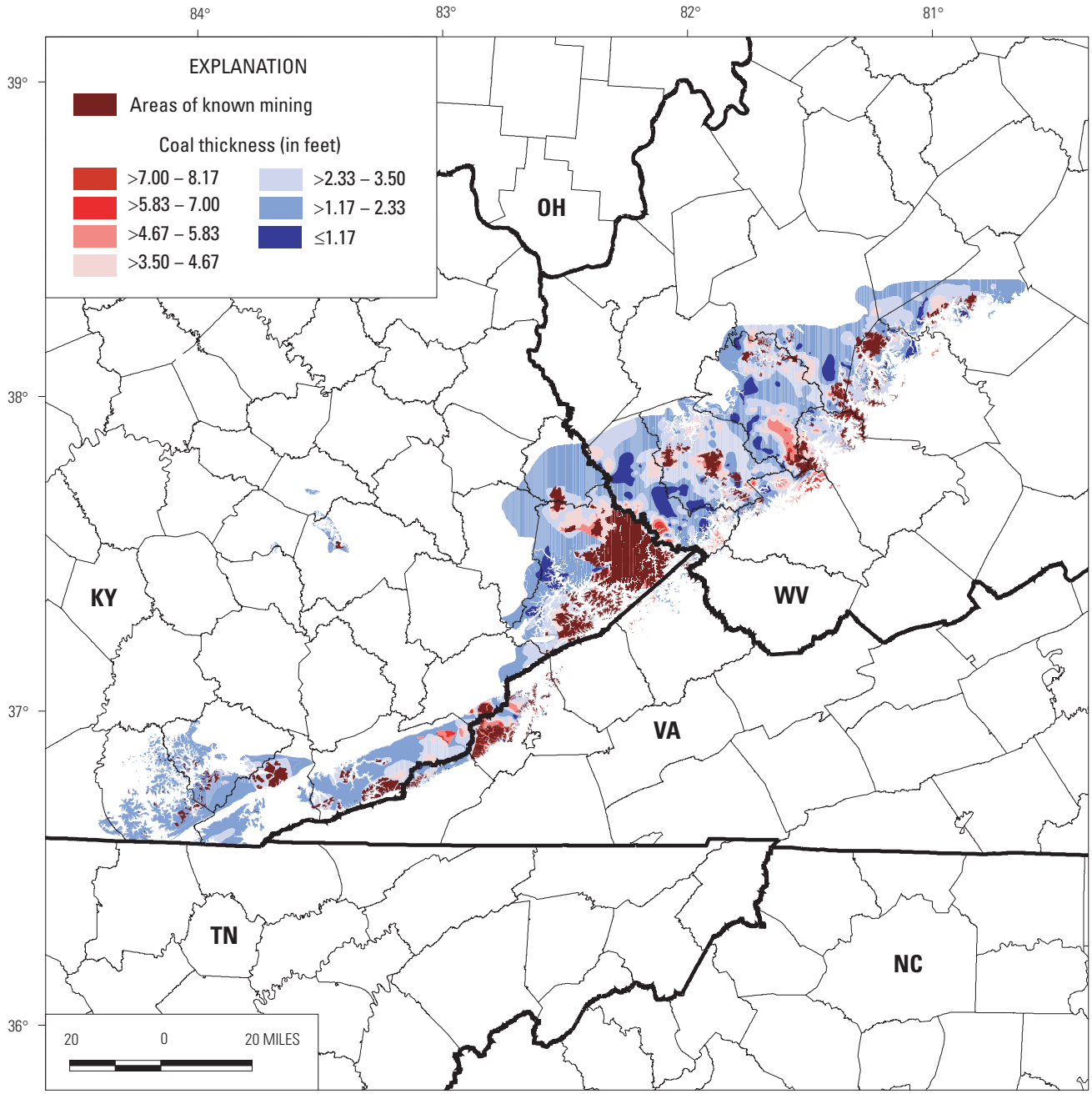

Figure 42. Map showing mined areas overlying thickness contours of the Pond Creek coal zone in Kentucky, Virginia, and West Virginia. See figure 4 for county names.

Table 19. Previous resource assessment estimates of the Pond Creek coal zone (Lower Elkhorn coal bed) coal in Kentucky (short tons).

[Sources: Brant (1983a,b); Brant, Chesnut, Frankie, and Portig (1983a,b,c); Brant, Chesnut, Portig, and Smath (1983). Abbreviations are as follows: nd, no data or absence of production data.]

County	Measured Total	Indicated Total	Inferred Total	Total >2.33 ft	Total >1.17 ft
Bell	19,569,452	79,070,943	155,774,289	97,283,566	254,414,687
Breathitt	12,341,582	34,360,017	37,930,559	38,897,350	84,632,156
Carter	332,690	127,290	nd	nd	459,980
Clay	2,092,783	10,858,519	3,303,761	8,270,494	16,255,062
Elliott	2,097,396	5,432,979	1,978,785	nd	9,509,160
Floyd	4,698,977	26,821,293	74,256,497	2,133,583	105,776,768
Harlan	47,072,790	231,479,864	723,531,163	590,244,954	1,002,083,818
Jackson	297,975	280,617	49,180	nd	627,772
Johnson	957,570	5,618,128	115,718	nd	6,691,416
Knott	906,273	7,175,913	26,542,015	10,392,769	34,624,202
Knox	33,440,600	126,160,282	223,590,068	30,200,649	383,190,951
Laurel	1,518,275	7,592,152	19,261,328	434,440	28,371,754
Lee	2,828,802	5,747,799	16,321,138	3,021,176	24,897,740
Letcher	8,643,784	6,427,141	208,998,935	203,127,732	278,069,860
Magoffin	650,916	1,365,477	34,716	nd	2,051,108
Martin	6,744,036	44,764,803	74,979,208	93,988,534	126,488,047
McCreary	407,907	2,609,449	28,333,650	nd	31,351,008
Morgan	nd	17,358	nd	nd	17,358
Owsley	2,654,646	6,306,785	3,361,009	3,970,464	12,322,439
Pike	326,974,474	925,996,291	659,818,995	1,628,113,819	1,912,789,760
Whitley	19,319,434	104,904,714	144,634,660	44,457,687	268,858,809
Wolfe	2,721,681	9,832,625	21,976,644	4,730,569	34,530,950
Grand Total	**496,272,043**	**79,070,943**	**2,424,792,318**	**2,759,267,786**	**4,618,014,805**

PREVIOUS RESOURCE STUDIES

Resource estimates for the Pond Creek and correlative beds in Kentucky were compiled in 1983 by investigators who worked with 1:24,000-scale geologic quadrangle maps (Brant, 1983a,b; Brant, Chesnut, Frankie, and Portig, 1983a,b,c; Brant, Chesnut, Portig, and Smath, 1983). Resource estimates (original resources) were made for the Pond Creek coal zone and equivalent beds in 22 counties in Kentucky and totaled about 4.6 billion short tons (table 19). Approximately 60 percent of the total was in beds greater than 2.33 ft thick. Pike County (fig. 5) was reported to have Pond Creek resources of more than 1.9 billion short tons, which is over 40 percent of the total Pond Creek resource for eastern Kentucky. Harlan County (fig. 5) had 1.0 billion short tons, or 22 percent, of the Pond Creek resources in eastern Kentucky. No other county had more than 9 percent. The KGS has published new resource estimates (Thacker and others, 2000) and coal-quality trends (Eble, 2000) for the Pond Creek coal zone based, in part, on cooperative work with the USGS National Coal Resource Assessment project. The reports were not available in time for incorporation into this assessment.

Brown and others (1952) reported on the Pond Creek coal resources of Virginia (the Imboden and Campbell Creek coal beds of the Wise Formation as used in that report). The total estimated remaining coal resources were 295.99 million short tons with 186.38 million short tons in Wise County, 55.48 million short tons in Lee County, 49.75 million short tons in Buchanan County, and 4.38 million short tons in Dickenson County (table 20). A more recent estimate of the coal resources of Lee County, Va., by Campbell and others (1991) reported that remaining resources were 122.3 million short tons (table 20), or about 2.2 times as much coal resources as the earlier estimate by Brown and others (1952). Campbell and others (1991) had the benefit of additional geologic mapping in the assessed area as well as additional drillhole data, including geophysical logs.

In West Virginia, resources of the Pond Creek coal zone (termed the Eagle coal bed and the No. 2 Gas coal bed) were assessed and reported upon in a series of county reports (Hennen, 1915, 1917, 1919; Hennen and Reger, 1914; Krebs, 1916; Krebs and Teets, 1913, 1914, 1915; Reger, 1921). The total Pond Creek resource for West Virginia was 5.669 billion short tons; Logan and Mingo Counties (fig. 5) had more than 1 billion short tons each; where combined, they contained 43 percent of the Pond Creek coal in the State (table 21). Although the Eagle and the No. 2 Gas coals in the 11 counties assessed in the county reports have been correlated with the Pond Creek coal zone, some of the coal beds assessed in these early reports may not necessarily be equivalent to those assessed in this study.

Table 20. Previous resource assessment estimates of the Pond Creek coal zone in Virginia.

[Sources: Brown and others (1952); Campbell and others (1991). Abbreviations are as follows: nd, no data or absence of data.]

Estimated resources for four Virginia counties
(Brown and others, 1952)

(Millions of short tons)

County	Measured	Indicated	Inferred	1.17 – 2.33 ft	2.33 – 3.50 ft	>3.50 ft	Total
Buchanan	nd	30.23	19.52	nd	49.75	nd	49.75
Dickenson	nd	2.18	2.20	nd	4.38	nd	4.38
Lee	5.07	21.76	28.65	29.15	16.39	9.94	55.48
Wise	15.08	93.54	77.76	35.27	70.80	80.31	186.38
Grand Total	20.15	147.71	128.13	64.42	141.32	90.25	295.99

Estimated resources for Lee County, Virginia
(Campbell and others, 1991)

(Millions of short tons)

County	Measured	Indicated	Inferred	1.17 – 2.33 ft	2.33 – 3.50 ft	>3.50 ft	Total
Lee	36.2	67.3	18.8	21.6	72.2	28.5	122.3

Table 21. Previous resource assessment estimates of the Pond Creek coal in West Virginia (short tons).

[Sources: Krebs and Teets (1913, 1914, 1915); Hennen and Reger (1914); Hennen (1915, 1917, 1919); Krebs (1916); Reger (1921).]

County	County Report Nomenclature	Short Tons
Boone	Eagle	117,089,280
Clay	Eagle	131,697,562
Fayette	Eagle	511,412,521
Kanawha	Eagle	200,724,480
Logan	No. 2 Gas	1,284,190,617
Lincoln	No. 2 Gas	390,297,600
McDowell	No. 2 Gas	10,705,305
Mingo	No. 2 Gas	1,163,923,200
Nicholas	Eagle	766,042,675
Raleigh	Eagle	441,593,856
Wayne	No. 2 Gas	651,016,397
Grand Total		5,668,693,493

RESULTS AND DISCUSSION

Overall, the thickest beds within the Pond Creek coal zone, and therefore the highest concentration of large-scale mining, has occurred in the eastern part of the assessment area (fig. 42) where the Pine Mountain thrust fault brings the coal close to the surface (fig. 43) and (or) multiple benches are present (figs. 8, 44). These benches represent the accumulation of additional peat mires after the burial of the main peat swamp in which most of the zone's beds formed (Greb and Weisenfluh, 2000). Local thickness variations in the Pond Creek coal zone are the result of the splitting of benches adjacent to paleochannels and tectonic structures. Additionally, dips and swags in underlying strata result in thickness changes within the coal (Greb and Weisenfluh, 2000). These features can affect the minability of the Pond Creek coal zone.

Thick (>4.67 ft) Pond Creek coal resources remain in Boone County, W. Va. (figs. 5, 42), but production is not expected to increase significantly until the overlying, thicker, and higher quality Alma/Powellton and Campbell Creek/Upper Elkhorn No. 3 coal zones (Chapter I, this report) are depleted. Smaller, but significant, occurrences of thick Pond Creek coal remain in Pike, Letcher, and Harlan Counties, Ky.; Wise County, Va.; and Mingo County, W. Va. (fig. 5), under relatively thick overburden (fig. 45).

The results of our resource calculations show that the total original resource of the Pond Creek coal zone was 11 billion short tons (table 1). Because the assessment area was limited to areas of sufficient data spacing, hypothetical resources of 400 million short tons are smaller than would normally be expected (Appendix 11). West Virginia, with 5.6 billion short tons of Pond Creek coal, had the largest original resource, followed by Kentucky with 4.6 billion short tons, and Virginia with 570 million short tons (table 1). The majority of the original Pond Creek coal resource was relatively shallow (fig. 21; Appendix 11). About 50 percent of the total original resource was overlain by less than 500 ft of overburden, almost 90 percent by less than 1,000 ft, and more than 99 percent by less than 2,000 ft. About 30 percent of the total Pond Creek original resource was thin (1.17–2.33 ft thick) and another 35 percent was >3.5 ft (fig. 20; Appendix 11). Just less than 70 percent of the total resource was clustered in the 2.33- to 7.0-ft thickness range.

Almost 45 percent of the original Pond Creek coal resource (fig. 5; table 1; Appendix 11) was located in Pike County, Ky. (2 billion short tons); Wise County, Va. (430 million short tons); and Boone and Logan Counties, W. Va. (1.2 billion short tons each). Over 18 percent of the total coal resource and over 40 percent of the total Kentucky resource was located in Pike County, Ky. (fig. 5; table 1), where the coal was thick (68 percent was 3.5–7.0 ft thick) and not very deep (over 99 percent was overlain by <1,000 ft of overburden; Appendix 11). In Virginia, 77 percent of the original resource and about 4 percent of the total original resource was in Wise County, Va. (fig. 5; table 1). About 65 percent of the total Wise County resource was thick (>3.5 ft) and relatively shallow (<1,000 ft of overburden; Appendix 11). Boone and Logan Counties, W. Va., contained 43 percent of the West Virginia resource and 22 percent of the total Pond Creek coal resource. Although about 80 percent of the combined Boone and Logan County total resource was relatively shallow (overlain by <1,000 of overburden; Appendix 11), it was also relatively thin (72 percent was in the 2.33–3.5 ft category; Appendix 11).

During the 1900's, a significant amount of the thick and shallow Pond Creek coal zone was mined (fig. 42). Our resource estimates show that, of the 11 billion original short tons, 8.7 billion short tons remain (table 1). Approximately 3.3 billion tons (72 percent) of the original resource remain in Kentucky; 370 million short tons (65 percent) of the original resource remain in Virginia; and 5 billion short tons (89 percent) of the original resource remain in West Virginia (Appendix 12). A large proportion (86 percent) of the remaining coal is relatively shallow (overlain by <1,000 ft of overburden), but over three-quarters of the remaining coal is thin (<3.5 ft thick). The Pond Creek coal zone has been the most extensively mined in Kentucky; only 18 percent of the thickest (>3.5 ft) and shallowest (<500 ft of overburden) coal remains unmined. In contrast, about 75 percent of the thickest (>3.5 ft) original coal resource in West Virginia remains unmined, chiefly because mining has been concentrated in the overlying Alma/Powellton and Campbell Creek/Upper Elkhorn No. 3 coal zones (Chapter I, this report).

The remaining coal resources in Pike and Harlan Counties, Ky. (fig. 5), constitute more than 50 percent of the remaining Pond Creek coal in the State. In Harlan County, 20 percent of the remaining coal resource is thicker than 3.5 ft, but two-thirds of the thick coal is overlain by more than 1,000 ft of overburden. Even though over one billion short tons of Pond Creek coal has been depleted from Pike County, Ky., 940 million short tons remain (table 1; Appendix 12). However, most of the thick coal has been mined (fig. 42) and only about 35 percent of the remaining coal is more than 3.5 ft thick.

Wise County has produced the majority of Virginia's Pond Creek coal (fig. 13; Appendix 5), and it contains the largest remaining tonnage (250 million short tons), which is about two-thirds of the remaining State resource of Pond Creek coal (table 1). Although the largest continuous thick blocks of coal have been mined (fig. 42), more than 50 percent of the State's remaining resource is thicker than 3.5 ft (fig. 20) and about 75 percent is overlain by less than 1,000 ft of overburden (fig. 21).

Almost 60 percent of the total remaining Pond Creek coal resource is in West Virginia (table 1). Nearly 90 percent of that resource is relatively shallow (overlain by <1,000 ft

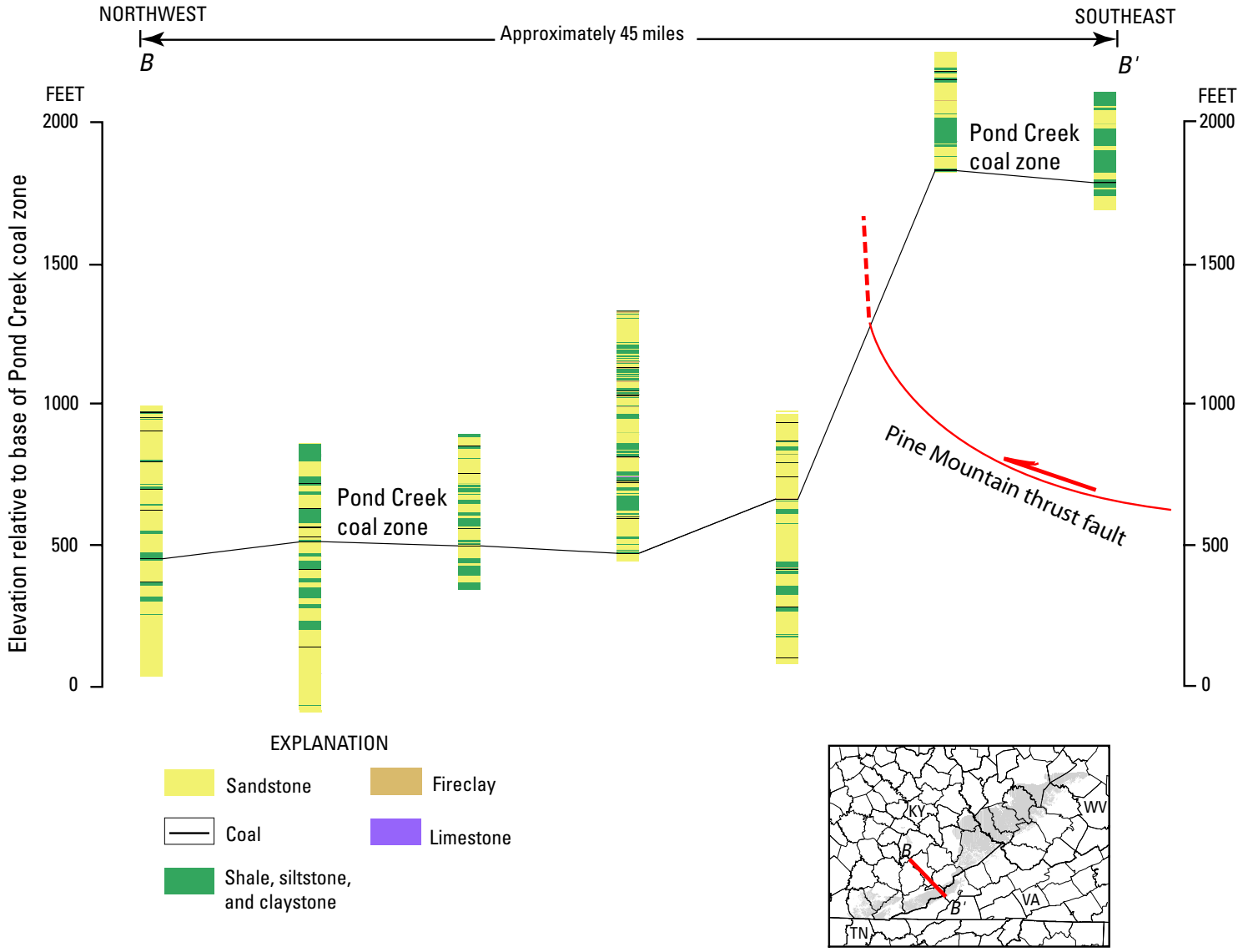

Figure 43. Generalized cross section (*B–B′*) trending northwest to southeast through Kentucky and Virginia. In this part of the basin, the Pond Creek coal zone is very thin. The Pine Mountain thrust fault is the primary structural control on the elevation of the Pond Creek coal zone southeast of the thrust fault. See figure 4 for county names. Vertical exaggeration X110.

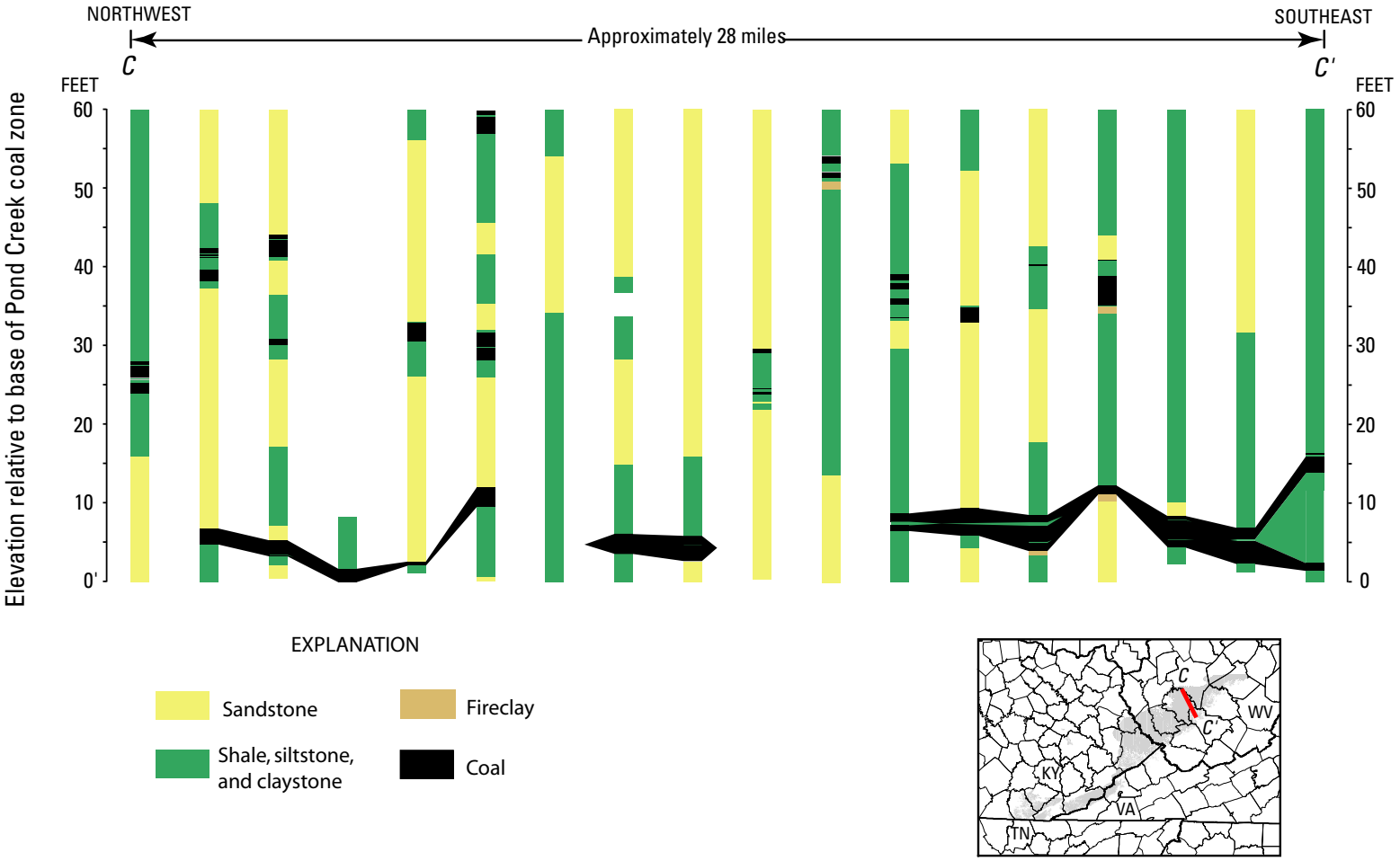

Figure 44. Generalized cross section (*C*–*C′*) trending northwest to southeast through West Virginia. The thickest Pond Creek coal, and the highest concentration of large-scale mining, is in the eastern part of the assessment area where multiple benches are present. See figure 4 for county names. Vertical exaggeration X2464.

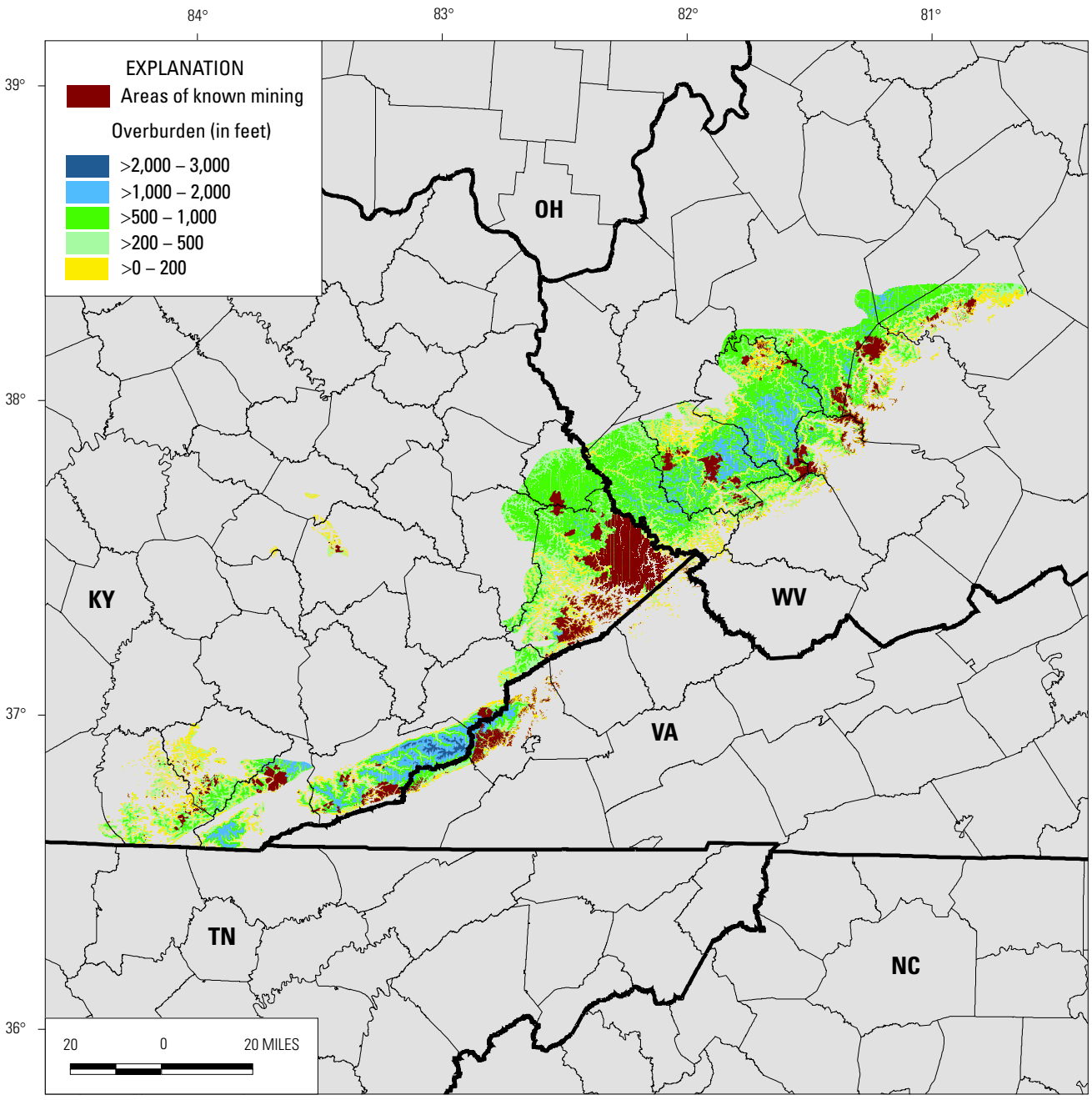

Figure 45. Map showing mined areas overlying the overburden thickness map of the Pond Creek coal zone. In general, coal thickness, and not overburden thickness, has controlled mining of the Pond Creek coal zone. One notable exception is the thick (>5.83 ft) pod of coal in Harlan County, Ky. (fig. 5), where overburden is >2,000 ft thick.

of overburden) but about 75 percent is relatively thin (<3.5 ft; Appendix 12). Boone County contains nearly a quarter of the State's remaining Pond Creek coal and the largest remaining continuous block thicker than 3.5 ft (fig. 42).

CONCLUSIONS

The Middle Pennsylvanian Pond Creek coal zone of the Pottsville Group is a valuable central Appalachian Basin coal resource because it is generally low in ash yield and sulfur content (7.24±3.98 and 1.05±0.77 weight percent, respectively, as-received whole-coal basis) and high in gross calorific value (13,540±650 Btu/lb). The coal is high-volatile A bituminous in rank and is mined and sometimes blended with coal that has higher ash yields and sulfur contents in order to comply with emission and combustion requirements. Of the original 11 billion short tons of Pond Creek coal, about 8.7 billion short tons remain. Kentucky has depleted the most Pond Creek coal (1.3 billion short tons), and the State's remaining resource (3.3 billion short tons) is thinner than the coal that has been mined. In Virginia, about 200 million short tons out of a total original resource of 570 million short tons has been mined and lost in mining. Approximately one-third of Virginia's total original resource has been depleted from Wise County (fig. 5), yet 250 million short tons remain in the county. Almost two-thirds of Virginia's Pond Creek original coal resource remains. West Virginia, which had the largest original Pond Creek coal resource (5.6 billion short tons), has the largest remaining resource (5.0 billion short tons). This resource has blocks of coal that are relatively thick and shallow, and could be exploited in the future.

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APPENDIX 1

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APPENDIX 2

POND CREEK COAL BED STRATIGRAPHIC DATABASE

[This ASCII file contains all of the public records used to model the Pond Creek coal bed and includes (1) record identifier, (2) longitude (decimal degrees), (2) latitude (decimal degrees), (4) elevation of the Pond Creek coal bed (feet above mean sea level), and (5) Pond Creek coal bed main bench thickness (ft), excluding parting. Records that contain a -999 in the elevation or thickness field represent invalid or unavailable data.]

CLICK HERE TO GO TO APPENDIX 2

APPENDIX 3

RECENT REPORTED ANNUAL PRODUCTION (IN SHORT TONS) OF THE POND CREEK COAL ZONE IN KENTUCKY, VIRGINIA, AND WEST VIRGINIA, ASSEMBLED FROM STATE AGENCIES

[Sources: Sweet, 1988, 1989, 1991; Sweet and Nolde, 1992, 1993, 1994, 1995, 1996, 1997a,b, 1998, 1999; Gayle H. McColloch (West Virginia Geological and Economic Survey, unpublished search of West Virginia Office of Miner's Health, Safety, and Training—Safety Information System (MHST-SIS) database, 1997; John K. Hiett, Kentucky Department of Mines and Minerals, written commun., 2000. Abbreviations are as follows: nd, no data or the absence of production]

Year	Kentucky	Virginia	West Virginia	Year	Kentucky	Virginia	West Virginia
1907	35,613	nd	nd	1954	2,683,841	nd	nd
1908	nd	nd	nd	1955	3,493,253	nd	nd
1909	21,715	nd	nd	1956	2,229,770	nd	nd
1910	1,777	nd	nd	1957	4,238,634	nd	nd
1911	10,516	nd	nd	1958	3,464,961	nd	nd
1912	64,872	nd	nd	1959	3,325,458	nd	nd
1913	33,033	nd	nd	1960	1,633,297	nd	nd
1914	119,071	nd	nd	1961	3,475,585	nd	nd
1915	nd	nd	nd	1962	3,378,201	nd	nd
1916	nd	nd	nd	1963	3,684,523	nd	nd
1917	nd	nd	nd	1964	6,059,768	nd	nd
1918	nd	nd	nd	1965	5,425,624	nd	nd
1919	nd	nd	nd	1966	7,384,388	nd	nd
1920	nd	nd	nd	1967	8,078,848	nd	nd
1921	1,806,006	nd	nd	1968	9,109,313	nd	nd
1922	2,972,174	nd	nd	1969	10,878,891	nd	nd
1923	2,893,097	nd	nd	1970	10,255,749	nd	nd
1924	1,131,910	nd	nd	1971	9,891,502	nd	nd
1925	1,207,316	nd	nd	1972	9,576,338	nd	nd
1926	1,347,157	nd	nd	1973	9,703,189	nd	nd
1927	1,455,917	nd	nd	1974	10,577,838	nd	nd
1928	894,942	nd	nd	1975	11,905,774	nd	nd
1929	1,826,449	nd	nd	1976	9,899,491	nd	nd
1930	1,672,357	nd	nd	1977	9,094,385	nd	nd
1931	1,365,379	nd	nd	1978	8,581,830	nd	nd
1932	1,170,641	nd	nd	1979	11,775,663	nd	nd
1933	1,260,114	nd	nd	1980	12,971,835	nd	nd
1934	1,042,954	nd	nd	1981	13,158,302	nd	nd
1935	1,073,176	nd	nd	1982	14,864,297	nd	5,667,335
1936	1,738,504	nd	nd	1983	11,329,909	nd	4,871,612
1937	2,207,920	nd	nd	1984	15,114,065	nd	5,648,755
1938	1,723,315	nd	nd	1985	17,055,764	894,774	5,832,911
1939	1,484,084	nd	nd	1986	15,998,382	644,854	6,532,109
1940	1,795,175	nd	nd	1987	17,920,852	753,162	7,203,832
1941	2,037,893	nd	nd	1988	15,312,203	1,034,698	5,747,759
1942	2,272,054	nd	nd	1989	16,018,472	642,869	5,456,842
1943	3,065,284	nd	nd	1990	16,866,868	214,789	5,940,256
1944	2,722,558	nd	nd	1991	15,815,798	377,698	6,249,346
1945	3,050,050	nd	nd	1992	13,707,591	212,709	5,995,184
1946	2,798,994	nd	nd	1993	12,589,367	1,472,095	4,339,893
1947	4,933,897	nd	nd	1994	14,064,440	1,923,040	7,292,282
1948	9,909,622	nd	nd	1995	15,107,863	1,764,284	8,113,383
1949	3,454,446	nd	nd	1996	14,571,761	1,539,720	11,012,027
1950	6,387,484	nd	nd	1997	9,257,534	1,332,638	nd
1951	4,158,340	nd	nd	1998	14,125,530	1,380,900	nd
1952	3,497,182	nd	nd				
1953	2,922,215	nd	nd				
				Total	539,222,150	14,188,230	95,903,526

APPENDIX 4

RECENT REPORTED ANNUAL PRODUCTION (IN SHORT TONS) OF THE POND CREEK COAL ZONE IN KENTUCKY, BY COUNTY

[Source: John K. Hiett, Kentucky Department of Mines and Minerals, written commun., 2000. Abbreviations are as follows: nd, no data or the absence of production]

Year	Bell	Breathitt	Clay	Floyd	Harlan	Jackson	Knott	Knox	Laurel	Lee	Leslie
1907	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1908	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1909	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1910	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1911	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1912	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1913	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1914	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1915	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1916	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1917	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1918	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1919	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1920	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1921	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1922	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1923	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1924	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1925	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1926	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1927	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1928	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1929	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1930	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1931	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1932	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1933	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1934	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1935	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1936	823,111	69,329	nd	35,434	nd	nd	nd	nd	nd	nd	nd
1937	637,211	60,250	3,000	15,508	nd	nd	nd	nd	nd	nd	nd
1938	528,217	61,650	nd	nd	nd	nd	nd	nd	120	nd	nd
1939	537,807	60,687	nd	nd	nd	nd	563	nd	4,987	nd	nd
1940	566,838	58,328	nd	nd	350	nd	nd	2,855	850	nd	nd
1941	494,407	nd	80	nd	nd	nd	nd	1,449	1,772	nd	nd
1942	451,505	nd	nd	nd	100	878	nd	197	nd	nd	nd
1943	447,747	47,518	nd	nd	nd	nd	nd	100,790	nd	nd	nd
1944	489,091	43,000	nd	nd	nd	nd	nd	157,171	nd	nd	nd
1945	371,722	31,700	nd	nd	865	625	nd	151,800	nd	nd	nd
1946	436,794	33,495	nd	nd	440	nd	nd	169,273	nd	nd	nd
1947	580,479	40,134	nd	nd	119	nd	nd	166,093	nd	nd	nd
1948	676,229	44,870	nd	nd	125	nd	nd	13,818	5,271	nd	nd
1949	771,366	54,862	nd	960	386	nd	nd	73,881	nd	nd	100
1950	721,854	44,776	nd	nd	nd	nd	nd	51,935	nd	nd	nd
1951	688,414	nd	nd	nd	nd	nd	nd	96,950	nd	nd	nd
1952	684,915	37,771	nd	nd	nd	nd	nd	43,727	nd	nd	nd

APPENDIX 4—CONTINUED

Year	Bell	Breathitt	Clay	Floyd	Harlan	Jackson	Knott	Knox	Laurel	Lee	Leslie
1953	574,539	46,502	nd	nd	nd	nd	nd	15,305	nd	nd	nd
1954	592,591	54,746	nd	nd	29,840	nd	nd	119,779	90,322	nd	nd
1955	562,162	42,832	nd	nd	13,800	nd	nd	203,120	nd	nd	nd
1956	78,045	nd	nd	nd	261	nd	nd	41,985	nd	nd	nd
1957	49,493	nd	nd	nd	211	nd	nd	63,094	nd	nd	nd
1958	53,171	nd	nd	nd	1,454	nd	nd	55,109	nd	nd	nd
1959	30,940	nd	nd	nd	690	nd	nd	52,911	nd	nd	nd
1960	6,085	nd	nd	nd	nd	nd	nd	32,620	nd	nd	nd
1961	31,181	nd	nd	nd	771	nd	nd	67,957	nd	nd	nd
1962	67,493	nd	nd	nd	75	nd	nd	120,967	nd	nd	nd
1963	1,305	nd	nd	nd	nd	nd	nd	126,954	nd	nd	nd
1964	3,350	nd	nd	nd	nd	nd	nd	135,949	nd	nd	nd
1965	160	nd	nd	nd	nd	nd	nd	98,470	nd	nd	nd
1966	11,750	nd	nd	nd	1,252	nd	nd	120,514	nd	nd	nd
1967	18,291	nd	nd	nd	nd	nd	nd	116,490	nd	nd	nd
1968	9,609	nd	26,502	nd	3,161	nd	nd	134,352	nd	nd	nd
1969	nd	nd	nd	nd	nd	nd	nd	130,199	nd	nd	nd
1970	74,000	nd	10,800	nd	nd	nd	nd	170,316	nd	nd	700
1971	51,181	nd	10,114	nd	nd	nd	nd	623,994	12,653	nd	nd
1972	3,104	nd	nd	nd	nd	nd	nd	331,817	132,088	nd	nd
1973	43,707	nd	nd	nd	nd	nd	nd	469,627	nd	nd	nd
1974	7,460	nd	nd	nd	21,565	32,536	nd	742,479	4,180	193,709	1,053
1975	115,877	nd	23,103	nd	51,650	115,580	nd	1,280,074	93,913	156,780	6,200
1976	nd	40,000	5,450	nd	31,462	474,559	nd	932,669	9,500	270,612	nd
1977	10,396	16,668	17,223	nd	6,125	19,429	nd	826,441	25,891	181,549	nd
1978	22,000	3,000	46,647	nd	27,362	50,000	nd	742,616	93,793	99,400	6,250
1979	5,775	25,000	28,680	nd	11,676	14,000	nd	744,443	19,480	131,334	1,100
1980	71,755	nd	5,229	nd	nd	41,000	nd	912,391	78,799	35,550	1,000
1981	275,095	nd	nd	nd	5,000	61,000	nd	1,041,056	250,337	34,627	nd
1982	21,399	nd	15,753	nd	138,268	66,850	nd	606,368	306,153	49,800	nd
1983	42,556	32,000	8,688	nd	265,984	40,700	nd	992,219	76,605	20,000	nd
1984	136,982	1,438	2,050	nd	435,142	62,550	nd	1,163,640	34,170	30,000	5,500
1985	169,414	100,594	1,483	nd	383,040	15,360	nd	1,346,722	13,623	114,690	nd
1986	109,092	nd	nd	nd	318,172	1,023	nd	1,214,692	8,401	34,379	nd
1987	119,097	17,744	nd	nd	513,954	nd	nd	1,191,768	6,100	4,000	nd
1988	124,638	56,000	nd	nd	689,947	2,715	nd	1,047,309	3,000	50,200	nd
1989	65,643	nd	nd	nd	613,900	nd	nd	816,337	nd	nd	nd
1990	19,841	nd	nd	nd	525,066	nd	nd	893,227	nd	nd	nd
1991	nd	1,100	nd	nd	373,943	nd	nd	652,338	nd	nd	nd
1992	nd	10,000	nd	nd	277,268	nd	nd	635,482	nd	nd	nd
1993	68,519	nd	nd	nd	222,545	nd	nd	673,227	nd	nd	nd
1994	49,969	nd	nd	nd	109,145	nd	nd	618,508	nd	nd	nd
1995	34,977	nd	nd	nd	219,937	nd	nd	494,909	nd	nd	nd
1996	2,000	nd	nd	51,901	212,547	nd	nd	561,248	nd	nd	nd
1997	nd	nd	nd	nd	nd	nd	nd	151,326	nd	nd	nd
1998	nd	nd	nd	89,978	260,216	nd	nd	564,936	nd	nd	nd
Total	15,260,375	1,182,999	234,972	204,360	5,768,054	998,805	563	25,845,201	1,272,008	1,406,630	50,452

APPENDIX 4—CONTINUED

Year	Letcher	Martin	McCreary	Morgan	Owsley	Perry	Pike	Whitley	Wolfe	Total annual production
1907	nd	nd	nd	nd	nd	nd	35,613	nd	nd	35,613
1908	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1909	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1910	nd	nd	nd	nd	nd	nd	21,715	nd	nd	21,715
1911	nd	nd	nd	nd	nd	nd	1,777	nd	nd	1,777
1912	nd	nd	nd	nd	nd	nd	10,516	nd	nd	10,516
1913	nd	nd	nd	nd	nd	nd	64,872	nd	nd	64,872
1914	nd	nd	nd	nd	nd	nd	33,033	nd	nd	33,033
1915	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1916	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1917	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1918	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1919	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1920	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1921	nd	nd	nd	nd	nd	nd	119,071	nd	nd	119,071
1922	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1923	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1924	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1925	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1926	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1927	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1928	nd	nd	nd	nd	nd	nd	1,806,006	nd	nd	1,806,006
1929	nd	nd	nd	nd	nd	nd	2,972,174	nd	nd	2,972,174
1930	nd	nd	nd	nd	nd	nd	2,893,097	nd	nd	2,893,097
1931	nd	nd	nd	nd	nd	nd	1,131,910	nd	nd	1,131,910
1932	nd	nd	nd	nd	nd	nd	1,207,316	nd	nd	1,207,316
1933	nd	nd	nd	nd	nd	nd	1,347,157	nd	nd	1,347,157
1934	nd	nd	nd	nd	nd	nd	1,455,917	nd	nd	1,455,917
1935	nd	nd	nd	nd	nd	nd	894,942	nd	nd	894,942
1936	nd	nd	nd	nd	nd	nd	898,575	nd	nd	1,826,449
1937	nd	nd	nd	nd	nd	nd	921,750	34,638	nd	1,672,357
1938	nd	nd	nd	nd	nd	nd	753,596	21,796	nd	1,365,379
1939	nd	nd	nd	nd	nd	nd	547,690	18,907	nd	1,170,641
1940	nd	nd	nd	nd	nd	nd	614,776	16,117	nd	1,260,114
1941	nd	nd	nd	nd	nd	nd	520,569	24,677	nd	1,042,954
1942	nd	nd	nd	nd	nd	nd	572,346	48,150	nd	1,073,176
1943	nd	nd	nd	nd	nd	nd	1,085,141	57,308	nd	1,738,504
1944	nd	nd	nd	nd	nd	nd	1,472,426	46,232	nd	2,207,920
1945	nd	nd	nd	nd	nd	nd	1,114,077	52,526	nd	1,723,315
1946	nd	nd	nd	nd	nd	nd	820,672	23,410	nd	1,484,084
1947	nd	nd	nd	nd	nd	90	950,175	58,085	nd	1,795,175
1948	nd	nd	nd	nd	nd	175	1,152,049	145,356	nd	2,037,893
1949	nd	nd	nd	nd	nd	nd	1,233,685	136,814	nd	2,272,054
1950	nd	nd	nd	nd	nd	nd	2,174,464	72,255	nd	3,065,284
1951	nd	nd	200	nd	nd	nd	1,822,992	114,002	nd	2,722,558
1952	nd	nd	400	nd	nd	nd	2,212,281	70,956	nd	3,050,050

APPENDIX 4—CONTINUED

Year	Letcher	Martin	McCreary	Morgan	Owsley	Perry	Pike	Whitley	Wolfe	Total annual production
1953	nd	nd	185	nd	nd	nd	2,129,173	33,290	nd	2,798,994
1954	nd	nd	30,240	nd	nd	nd	3,866,981	149,398	nd	4,933,897
1955	nd	nd	nd	nd	nd	nd	9,060,383	27,325	nd	9,909,622
1956	nd	nd	nd	nd	nd	nd	2,090,246	19,233	nd	2,229,770
1957	nd	nd	nd	nd	nd	nd	4,114,692	11,144	nd	4,238,634
1958	nd	nd	nd	nd	nd	nd	3,326,781	28,446	nd	3,464,961
1959	nd	nd	nd	nd	nd	nd	3,217,233	23,684	nd	3,325,458
1960	nd	nd	3,000	nd	nd	nd	1,590,012	1,580	nd	1,633,297
1961	nd	nd	nd	nd	nd	nd	3,359,087	16,589	nd	3,475,585
1962	39,850	64,189	nd	nd	nd	nd	3,067,858	17,769	nd	3,378,201
1963	235,237	nd	nd	nd	nd	nd	3,305,057	15,970	nd	3,684,523
1964	733,700	nd	nd	nd	nd	nd	5,156,871	29,898	nd	6,059,768
1965	953,885	nd	nd	nd	nd	nd	4,325,286	47,823	nd	5,425,624
1966	799,420	nd	nd	nd	nd	nd	6,389,654	61,798	nd	7,384,388
1967	927,517	nd	nd	nd	nd	nd	6,976,974	39,576	nd	8,078,848
1968	716,595	nd	nd	nd	nd	nd	8,158,734	60,360	nd	9,109,313
1969	484,026	nd	nd	nd	nd	nd	10,221,739	42,927	nd	10,878,891
1970	649,599	nd	nd	nd	nd	nd	9,111,811	238,523	nd	10,255,749
1971	569,364	nd	nd	nd	28,000	nd	8,034,697	561,499	nd	9,891,502
1972	454,771	nd	nd	nd	26,450	nd	7,941,129	686,979	nd	9,576,338
1973	535,987	nd	nd	nd	57,166	nd	7,816,480	780,222	nd	9,703,189
1974	646,827	nd	nd	nd	161,135	nd	7,457,566	1,309,328	nd	10,577,838
1975	618,944	nd	40,000	nd	196,133	nd	7,103,417	2,104,103	nd	11,905,774
1976	108,586	67,749	nd	nd	187,241	nd	6,495,323	1,236,229	40,111	9,899,491
1977	75,359	435,272	15,099	nd	193,228	nd	5,813,128	1,428,639	29,938	9,094,385
1978	215,260	862,880	22,971	nd	204,227	nd	4,738,652	1,428,752	18,020	8,581,830
1979	243,161	1,073,224	27,150	nd	212,068	nd	8,173,094	1,015,478	50,000	11,775,663
1980	457,559	1,142,655	1,801	nd	55,245	nd	9,533,269	630,601	4,981	12,971,835
1981	512,902	1,368,698	nd	nd	12,500	nd	8,820,273	776,814	nd	13,158,302
1982	534,397	1,570,513	nd	nd	57,600	nd	10,567,413	929,783	nd	14,864,297
1983	312,982	374,485	nd	nd	3,750	nd	8,352,220	807,720	nd	11,329,909
1984	648,799	1,324,885	1,000	nd	7,200	nd	10,431,786	828,923	nd	15,114,065
1985	559,821	1,688,348	nd	nd	nd	nd	11,978,960	683,709	nd	17,055,764
1986	721,574	1,152,249	nd	nd	33,291	nd	11,694,822	710,687	nd	15,998,382
1987	1,319,426	1,873,778	nd	nd	18,500	nd	11,904,082	952,403	nd	17,920,852
1988	1,602,262	1,300,040	nd	nd	5,411	nd	9,488,143	942,538	nd	15,312,203
1989	1,314,920	1,339,499	nd	nd	nd	nd	10,669,556	1,198,617	nd	16,018,472
1990	1,120,516	1,640,253	nd	nd	nd	nd	11,573,563	1,094,402	nd	16,866,868
1991	849,824	1,866,037	nd	nd	nd	nd	11,461,481	611,075	nd	15,815,798
1992	nd	1,715,426	nd	nd	nd	nd	10,222,730	846,685	nd	13,707,591
1993	nd	1,503,879	nd	nd	nd	nd	9,372,546	748,651	nd	12,589,367
1994	53,619	1,610,910	nd	nd	nd	nd	10,698,620	923,669	nd	14,064,440
1995	10,635	2,356,287	nd	nd	nd	nd	11,161,789	829,329	nd	15,107,863
1996	nd	1,961,885	nd	nd	nd	nd	11,466,669	315,511	nd	14,571,761
1997	nd	2,071,088	nd	nd	nd	nd	7,027,563	7,557	nd	9,257,534
1998	42,451	1,384,908	nd	nd	nd	nd	11,652,966	130,075	nd	14,125,530
Total	19,069,775	31,769,236	249,346	91,422	1,459,145	265	407,583,817	26,631,675	143,050	539,222,150

APPENDIX 5

RECENT REPORTED ANNUAL PRODUCTION (IN SHORT TONS) OF THE POND CREEK COAL ZONE IN VIRGINIA, BY COUNTY

[Sources: Sweet, 1988, 1989, 1991; Sweet and Nolde, 1992, 1993, 1994, 1995, 1996, 1997a,b, 1998, 1999. Abbreviations are as follows: nd, no data or the absence of production]

Year	Buchanan	Dickenson	Lee	Wise	Total annual production
1985	nd	nd	22,741	872,033	894,774
1986	29,461	nd	21,100	594,293	644,854
1987	37,268	8,231	nd	707,663	753,162
1988	99,784	nd	nd	934,914	1,034,698
1989	61,588	nd	nd	581,281	642,869
1990	nd	nd	nd	214,789	214,789
1991	nd	nd	nd	377,698	377,698
1992	323	nd	nd	212,386	212,709
1993	46,021	nd	nd	1,426,074	1,472,095
1994	38,829	nd	nd	1,884,211	1,923,040
1995	75,727	nd	492,662	1,195,895	1,764,284
1996	105,010	nd	411,075	1,023,635	1,539,720
1997	51,557	nd	394,343	886,738	1,332,638
1998	25,740	nd	158,093	1,197,067	1,380,900
Total	571,308	8,231	1,500,014	12,108,677	14,188,230

APPENDIX 6

RECENT REPORTED ANNUAL PRODUCTION (IN SHORT TONS) OF THE POND CREEK COAL ZONE IN WEST VIRGINIA, BY COUNTY

[Source: Gayle H. McColloch (West Virginia Geological and Economic Survey, unpublished search of West Virginia Office of Miner's Health, Safety, and Training—Safety Information System (MHST-SIS) database, 1997. Abbreviations are as follows: nd, no data or the absence of production]

Year	Boone	Mingo	Nicholas	Raleigh	Wyoming	Total annual production
1982	1,333,141	1,215,977	1,216,752	885,084	1,016,381	5,667,335
1983	2,068,675	835,060	1,112,786	691,832	163,259	4,871,612
1984	1,598,304	704,515	1,855,484	745,734	744,718	5,648,755
1985	1,771,973	870,188	1,613,048	759,955	817,747	5,832,911
1986	2,067,236	1,669,792	1,185,683	830,599	778,799	6,532,109
1987	2,154,130	1,833,711	1,430,735	765,804	1,019,452	7,203,832
1988	1,569,134	1,124,926	1,617,804	334,419	1,101,476	5,747,759
1989	1,697,810	1,073,914	1,139,755	191,580	1,353,783	5,456,842
1990	1,838,314	1,499,333	1,113,569	91,195	1,397,845	5,940,256
1991	2,129,434	1,731,207	829,111	172,994	1,386,600	6,249,346
1992	1,989,655	1,334,334	671,134	859,420	1,140,641	5,995,184
1993	1,408,766	1,044,585	479,692	836,997	569,853	4,339,893
1994	4,218,437	674,242	443,679	1,674,201	281,723	7,292,282
1995	4,394,747	515,857	367,633	2,775,324	59,822	8,113,383
1996	4,068,784	667,550	595,049	5,453,450	227,194	11,012,027
Total	34,308,540	16,795,191	15,671,914	17,068,588	12,059,293	95,903,526

APPENDIX 7

POND CREEK COAL ZONE GEOCHEMICAL DATABASE

[This ASCII file contains all of the public records used to model the coal quality for the Pond Creek coal zone and includes NCAID (northern and central Appalachian index number used for bed data records), source, State, county, longitude (decimal degrees), latitude (decimal degrees), coal province, coal region, coal field, district, coal group, coal bed, sample thickness (feet), system, series/epoch, comments, map, collector, pointid (field identification number), estimated rank, lab code, sample type, analytical type, value represented, total moisture (percent), volatile matter (percent), fixed carbon (percent), ASTM ash (American Society for Testing and Materials; percent), hydrogen (percent), carbon (percent), nitrogen (percent), oxygen (percent), sulfur (percent), SO_2 (lbs/million Btu), gross calorific value (Btu/lb), air dried loss (percent), sulfate sulfur (percent), pyritic sulfur (percent), organic sulfur (percent), free swelling index, ash deformation temperature (degrees Fahrenheit), ash softening temperature (degrees Fahrenheit), ash fluid temperature (degrees Fahrenheit), Hardgrove grindability index, USGS ash (U.S. Geological Survey; percent), Si (percent), Al (percent), Ca (percent), Mg (percent), Na (percent), K (percent), Fe (percent), Ti (percent), S (percent), Ag (ppm), As (ppm), B (ppm), Ba (ppm), Be (ppm), Bi (ppm), Br (ppm), Cd (ppm), Ce (ppm), Cl (ppm), Co (ppm), Cr (ppm), Cs (ppm), Cu (ppm), Dy (ppm), Er (ppm), Eu (ppm), F (ppm), Ga (ppm), Gd (ppm), Ge (ppm), Hf (ppm), Hg (ppm), Ho (ppm), La (ppm), Li (ppm), Lu (ppm), Mn (ppm), Mo (ppm), Nb (ppm), Nd (ppm), Ni (ppm), P (ppm), Pb (ppm), Pr (ppm), Rb (ppm), Sb (ppm), Sc (ppm), Se (ppm), Sm (ppm), Sn (ppm), Sr (ppm) Ta (ppm), Tb (ppm), Th (ppm), Tl (ppm), U (ppm), V (ppm), W (ppm), Y (ppm), Yb (ppm), Zn (ppm), Zr (ppm)].

CLICK HERE TO GO TO APPENDIX 7

APPENDIX 8

METADATA FOR THE POND CREEK COAL ZONE GEOCHEMICAL DATABASE

CLICK HERE TO GO TO APPENDIX 8

APPENDIX 9

REFERENCES FOR THE POND CREEK COAL ZONE GEOCHEMICAL DATABASE

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APPENDIX 11

ORIGINAL COAL RESOURCES BY OVERBURDEN, RELIABILITY, AND COAL-BED-THICKNESS CATEGORIES, AND BY STATE AND COUNTY, FOR THE POND CREEK COAL ZONE

[Resources are rounded to millions of short tons and two significant figures. Reliability categories are as follows: identified, resources calculated for area within 3 mi of a coal-thickness measurement; hypothetical, resources calculated for area farther than 3 mi from a coal-thickness measurement. Asterisk indicates less than 10,000 short tons; St., State.]

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APPENDIX 12

REMAINING COAL RESOURCES BY OVERBURDEN, RELIABILITY, AND COAL-BED-THICKNESS CATEGORIES, AND BY STATE AND COUNTY, FOR THE POND CREEK COAL ZONE

[Resources are rounded to millions of short tons and two significant figures. Reliability categories are as follows: identified, resources calculated for area within 3 mi of a coal-thickness measurement; hypothetical, resources calculated for area farther than 3 mi from a coal-thickness measurement. Asterisk indicates less than 10,000 short tons; St., State.]

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